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(54) Title: ONCOLYTIC VIRUS

(57) Abstract: The present invention is directed to a method of reducing the viability of a tumor cell involving administering a virus that is not a common human pathogen to the tumor cell. Preferably, the virus exhibits differential susceptibility, in that normal cells are not affected by the virus. This differential susceptibility is more pronounced in the presence of interferon. The tumor cell is characterized by having low levels, or no, PKR activity, or as being PKR<sup>-/-</sup>, STAT1<sup>-/-</sup> or both PKR<sup>-/-</sup> and STAT1<sup>-/-</sup>. The virus is selected from the group consisting of Rhabdovirus and picornavirus, and preferably is vesicular stomatitis virus (VSV) or a derivative thereof.



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## ONCOLYTIC VIRUS

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This application claims the benefit of U.S. Provisional Application No. \_\_\_\_\_, having an effective filing date of September 17, 1999, as obtained by the petition dated September 8, 2000 under 37 CFR 1.53(c)(2) from U.S. Application No. 09/397,873, filed September 17, 1999, the contents of which are incorporated herein by reference.

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The present invention relates to a novel cancer therapeutic. More specifically, this invention relates to viruses that selectively infect and inhibit tumour cell growth.

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## BACKGROUND OF THE INVENTION

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The use of oncolytic bacteria, or compositions of oncolytic bacterias, for combatting neoplasms in humans and animals is known. For example EP 564 121, GB 1,587,244 and U.S. 3,192,116 disclose the use of non-pathogenic bacteria that result in the liquification and lysis of tumours in vertebrates. However in many instances, for example with the use of *Clostridium*, the tumours are only partially destroyed, and tumour regrowth may still occur. To ensure control of tumour growth the administration of bacteria, followed by chemotherapeutic drugs, for example 5-fluorodeoxyuridine or alkylating agents, has been suggested (e.g. GB 1,069,144).

25

30

Several viruses have also been shown to exhibit tumoricidal properties, for example parvovirus H-1 (Dupressoir et al., 1996. Cancer Res, 49:3203-3208), Newcastle disease virus (Reichand et al., 1992. J. Surg. Res, 52:448-453) or retroviral vectors containing drug susceptibility genes (Takamiya et al., 1993. J. Neurosurg, 79:104-110). WO97/26904 and WO96/03997 disclose a mutant herpes simplex virus (HSV-1761) that inhibits tumour cell growth. Administration of HSV-1716 comprising a 759 base pair deletion in each copy of  $\gamma$ 34.5 of the long repeat region



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(R<sub>L</sub>) to tumour cells kills these cells. However, this virus is specific for neuronal cells as HSV is known to selectively inhabit the neuronal system. Furthermore, the use of common human pathogens as an oncolytic virus is limited as it is likely that the general population has been infected and acquired an immune response to such viruses. A preexisting immune response to a viral strain similar to the one used as a therapeutic agent in the treatment of a cancer may attenuate the effectiveness of the virus as therapeutic agent.

Other virus strains have reported oncolytic activity. The ONYX-015 human adenovirus (produced by ONYX pharmaceuticals) is believed to replicate preferentially in p53 negative tumour cells. This virus shows promise in clinical trials with head and neck cancer patients (Kirn, D., T. et al., Nat Med, 1998. 4:1341-1342). Reovirus type 3 is being developed by Oncolytic Biotech as a cancer therapeutic, which preferentially grows in PKR -/- cells (Yin, H.S., J Virol Methods, 1997. 67:93-101; Strong, J.E. and P.W. Lee., J Virol, 1996. 70:612-616; Strong, J.E., et al., Virology, 1993. 197:405-411; Minuk, G.Y., et al., J Hepatol, 1987. 5:8-13; Rozee, K.R., et al., Appl Environ Microbiol, 1978. 35:297-300). Reovirus, type III exhibited enhanced replication properties in cells which expressed the mutant ras oncogene (Coffey, M.C., et al., Science, 1998. 282:1332-1334; Strong, J.E., et al., Embo J, 1998. 17:3351-1362). Mundschau and Faller (Mundschau, L.J. and D.V. Faller, J Biol Chem, 1992. 267:23092-23098) have shown that the ras oncogene product activated an inhibitor of PKR, and this coupled with the observation that the PKR chemical inhibitor 2-aminopurine increased the growth of Reo type III in normal cells implicates PKR is a critical regulator of the growth of reovirus.

W0 99/04026 teaches the use of VSV as a vector in gene therapy for the expression of a wide range of products including antibodies, immunogens, toxins, etc. for the treatment of a variety of disease disorders.

Interferons are circulating factors which bind to cell surface receptors activating a signalling cascade ultimately leading to a number of biological responses.



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Two of the outcomes of interferon signalling are tightly linked: (1) an antiviral response and (2) induction of growth inhibitory and/or apoptotic signals.

U.S. 4,806,347 discloses the use of  $\gamma$  Interferon and a fragment of INF- $\gamma$   
5 (known as  $\Delta 4\alpha 2$ ) against human tumour cells.

WO 99/18799 reports the cytotoxic activity of Newcastle Disease Virus (NDV) and Sindbis virus towards several human cancer cells. However, both viruses demonstrated selectivity in their cytotoxic activity towards tumor cells.

10

WO 99/18799 discloses that interferon addition to normal cells renders these cells resistant to NDV, yet, this effect was not observed with interferon-treated tumor cells which continued to exhibit NDV-induced sensitivity. WO 99/18799 also discloses the cytotoxic activity of VSV cells against KB cells (head and neck  
15 carcinoma) and HT 1080 (Fibrosarcoma), and alleviation of cytotoxicity in normal and tumor cells, by VSV, in the presence of interferon. No other cell types were tested against VSV cytotoxic activity.

Certain mutant strains of VSV have been reported. Stanners, et al., Virology  
20 (1987) 160(1):255-8. Francoeur, et al., Virology (1987) 160(1):236-45. Stanners, et al., J. Gen. Virol. (1975) 29(3):281-96. Stanners, et al., Cell (1977) 11(2):273-81.

The present invention relates to viral formulations that are useful in the treatment of diseases and cancers, preferably leukaemia. Such formulations may also  
25 comprise an oncolytic VSV strain and a chemical agent, for example a cytokine which confers to normal cells, resistance to viral infection, but leaves diseased or cancerous cells susceptible to viral infection and lysis.

It is an object of the invention to overcome disadvantages of the prior art.

30

The above object is met by the combinations of features of the main claims, the sub-claims disclose further advantageous embodiments of the invention.



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**SUMMARY OF THE INVENTION**

The present invention relates to a novel cancer therapeutic. More specifically, this invention relates to viruses that selectively infect and inhibit tumour cell growth.

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According to the present invention there is provided a method of reducing the viability of a tumour cell comprising administering a virus to the tumour cell, wherein the virus is characterized as not being a common human pathogen. Preferably the tumour cell lacks PKR activity, and the virus is selected from the group consisting of rhabdovirus. More preferably the virus is VSV.

10

This invention is also directed to a method of reducing the viability of a tumour cell comprising administering a virus to the tumour cell, wherein the virus is characterized as being unable to inactivate PKR activity within a host cell. Preferably the virus is selected from the group consisting of vesicular stomatitis virus, picornavirus, influenza virus, and adenovirus.

15

The present invention also pertains to a method of reducing the viability a tumour cell within a population of cells comprising administering a virus to the population of cells, wherein the virus is characterized as being able to selectively infect and kill the tumour cell. Preferably the virus is further characterized by being unable to inactivate PKR activity in a host cell.

20

This invention also relates to the method as defined above, wherein the population of cells is treated with interferon prior to administering the virus.

25

This invention provides a method for identifying a tumor susceptible to treatment with a virus, comprising: (a) dividing a sample containing cells of the tumor into a first portion and a second portion; (b) treating the first portion with the virus; and (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion, wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion.

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- 5 -

This invention provides a method for identifying a tumor susceptible to treatment with a virus, comprising: (a) dividing a sample containing cells of the tumor into a first portion and a second portion; (b) treating the first portion with the virus and an amount of interferon sufficient to improve survival of interferon-responsive cells in the presence of the virus, and treating the second portion with the virus in the absence of interferon; and (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion, wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion.

The present invention is directed to a mutant VSV, characterized in that the mutant VSV grows poorly in interferon-responsive cells. Such strains are also referred to herein as attenuated strains of VSV, or VSV strains that grow poorly in interferon-responsive cells. They can be identified by their producing smaller plaques in monolayers of interferon-responsive cells than in interferon-nonresponsive cells, as described below. Attenuated VSV strains can also be identified by their having a higher LD50 when administered intranasally to PKR+/- mice as compared to WT Indiana, in the assay described below.

The present invention also pertains to a method for isolating VSV using an affinity matrix, comprising adding the VSV to the affinity matrix to produce bound VSV, washing the bound VSV, and eluting the VSV from the affinity matrix. Also included in the present invention is a modified VSV that comprises a non-native fusion protein on the outer surface of the virus. The non-native protein may be fusion protein comprising an affinity tag and a viral envelope protein, or it may be derived from a producer cell.

The present invention is also directed to isolated nucleic acid molecules (DNA or RNA) having a sequence coding for mutant VSV proteins and sequences



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complementary thereto. Such nucleic acid molecules can be used in the preparation of a recombinant VSV or as a DNA vaccine.

There are several advantages for the use of a virus as described herein as a  
5 therapeutic virus over other viruses:

- Rhabdoviruses are not common human pathogens. For example, VSV is found mostly in insects, rodents and domestic farm animals, and therefore a large proportion of individuals will not have been infected or immunized to VSV infection. On the other hand, Adenovirus or Reovirus are human  
10 pathogens and most of the general population have been infected and acquired an immune response to both of these viruses. A preexisting immune response to a viral strain similar to the one used as a therapeutic agent in the treatment of a cancer may attenuate the effectiveness of the virus as therapeutic agent;  
15
- VSV replicates much more quickly than either Adenovirus or Reovirus, and can be readily concentrated to high titres. Production of high titre virus preparations is a significant limitation of other potential viral therapeutic strains;  
20
- VSV is simple virus comprising only five genes, easily amenable to genetic manipulation. No such system is currently available for Reovirus;
- Cellular infection by VSV is highly responsive to additional chemical agents  
25 such as interferon, a feature which enhances its therapeutic value.
- VSV has a broad host range and is capable of infecting most types of human cells, whereas other viruses are more limited in regard to the types of cells they may infect.  
30
- VSV is a RNA virus and spends its entire lifecycle in the cytoplasm. Therefore it involves less danger of unwanted integration into the genome of a patient.



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Collectively, these VSV attributes provide significant advantages over the use of the other viruses known to exhibit oncolytic activity.

- 5           This summary of the invention does not necessarily describe all necessary features of the invention but that the invention may also reside in a sub-combination of the described features.



**BRIEF DESCRIPTION OF THE DRAWINGS**

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

5

**FIGURE 1** shows a general schematic of the interferon cascade.

**FIGURE 2** shows the effect of VSV on normal human fibroblasts, human melanoma cell line SK-MEL3, LNCaP a prostate cancer cell line, and the ovarian carcinoma cell  
10 A2780 in the presence and absence of interferon as determined by a modified cpe assay. Monolayers of cells were infected at an moi of 0.1 pfu in a 12 well plate. At time 0 and every 12 hours subsequent up to 48 hours, one well of infected cells was fixed with 0.5 ml Leukostat fixative for 2 minutes. At the end of the experiment monolayers were stained with Leukostat stains.

15

**FIGURE 3** shows the cytopathic effect of VSV in normal fibroblasts cells (Figure 3 (a)), and tumour cell lines, including ovarian tumour cells (Figure 3 (b)) and KB tumour cells (Figure 3 (c)).

**FIGURE 4** shows the effect of VSV on normal human fibroblasts co-cultured with  
20 293T tumour cells over a period of 24 hours. Co-cultures were infected at an moi of 0.1 pfu/cell and the infection allowed to proceed in the presence (IFN+) or absence (IFN-) of interferon. Cultures were stained with antibodies to large T antigen (red nuclei) to detect the 293T cells and with DAPI (blue nuclei) which stains all cell  
25 types.

**FIGURE 5** shows the effect of VSV *in vivo* on tumors implanted within nude mice. Human melanoma cells were implanted within nude mice and either mock injected (VSV(-)), injected with wild type VSV (data not presented), or injected with  
30 additional melanoma cells infected in vitro with VSV for one hour prior to injection into the tumour site VSV(+)). Size of the tumors were determined over a 7 day period.



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**FIGURE 6** shows ulcers formed on a tumor produced within a nude mouse as described in Figure 5.

5     **FIGURE 7:** VSV and VSV infected cells inhibit growth of human melanoma xenografts in nude mice.

**FIGURES 8A and 8B:** PKR  $-/-$  mice are acutely sensitive to intranasal VSV infection and demonstrate a deficiency in IFN mediated resistance.

10

**FIGURE 9:** Interferon can protect xenograft bearing nude mice during VSV treatment.

15     **FIGURES 10A and 10B:** Virus production from tumour cells and normal cells infected with wild type Indiana and various mutant VSV strains.

**FIGURE 11:** Malignant cells are rapidly killed following VSV (WT Indiana) infection and are not protected by IFN- $\alpha$ .

20     **FIGURE 12:** VSV induced cytopathic effect visible in human melanoma cells but not in primary human cells with or without IFN- $\alpha$ .

**FIGURE 13:** Efficacy of a single intravenous dose of mutant VSV in treating human melanoma xenografts in nude mice.

25

**FIGURE 14:** N Protein cDNA sequence of wild type and mutant VSVs.

**FIGURE 15:** N Protein amino acid sequence of wild type and mutant VSVs.

30     **FIGURE 16:** P Protein cDNA sequence of wild type and mutant VSVs.

**FIGURE 17:** P Protein amino acid sequence of wild type and mutant VSVs.



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**FIGURE 18:** M Protein cDNA sequence of wild type and mutant VSVs.

**FIGURE 19:** M Protein amino acid sequence of wild type and mutant VSVs.

5

**FIGURE 20:** G Protein cDNA sequence of wild type and mutant VSVs.

**FIGURE 21:** G Protein amino acid sequence of wild type and mutant VSVs.

10

**FIGURE 22:** L Protein cDNA sequence of wild type and mutant VSVs.

**FIGURE 23:** L Protein amino acid sequence of wild type and mutant VSVs.



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**DESCRIPTION OF PREFERRED EMBODIMENTS**

The present invention relates to a novel cancer therapeutic. More specifically, this invention relates to viruses that selectively infect and inhibit tumour cell growth.

5

The following description is of a preferred embodiment by way of example only and without limitation to the combination of features necessary for carrying the invention into effect.

10

Cancer cells gain a survival advantage over their normal counterparts by acquiring mutations in growth inhibitory or apoptotic pathways and, in the case of interferons, would do so at the expense of critical antiviral defence mechanisms. As tumour cells gain a significant growth advantage by mutating interferon response genes, they will be more susceptible to virus infection.

15

By “reducing the viability” of a tumour cell it is meant either killing the tumour cell or limiting its growth for a period of time.

20

By “not a common human pathogen” it is meant a virus that is found mostly in non-human hosts, for example, but not limited to insects, rodents, and farm animals. Such viruses are not typically found within the general human population.

25

As used herein Mutant I, Mutant 1, Mut 1 and M1 refer to attenuated mutant strain T1026. Mutants II, III, IV and V (and variant nomenclature analogous to Mutant I) refer to attenuated mutants T1026R, TP3, TP6 and G31, respectively.

30

The novel cancer therapeutic of the present invention incorporates the use of at least one oncolytic virus that selectively targets tumour cells and leads to their destruction. Preferably the oncolytic virus is a Vesicular stomatitis virus (VSV), for example the Indiana strain, or other strains, or a derivative thereof. By a derivative of VSV, it is meant a VSV virus obtained by either selecting the virus under different growth conditions, or one that has been subjected to a range of selection pressures, or



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one that has been genetically modified using recombinant techniques known within the art. For example, which are not to be considered limiting in any manner, a derivative of VSV may include a mutant VSV selected following infection on a human cell that has been treated with interferon as described herein, or a VSV that displays an affinity tag useful for affinity purification.

The effectiveness of oncolytic virus suppression of tumour cell growth in part resides in the differential susceptibility of tumour cells, compared to normal cells, to viral infection. Without wishing to be bound by theory, the differential susceptibility may in part be due to the down regulation or inactivation of factors within a cell that otherwise function to protect the cell from tumorous growth and virus infection. Examples of factors that when inactivated result in tumorous cell growth, and that are also involved in mediating virus infection include but are not limited to PKR (double stranded RNA dependent kinase) and PML (Promyelocytic Leukemia gene), however, it is to be understood that other factors may also play a role.

The down regulation or inactivation of PKR, through a variety of mechanisms including but not limited to PKR-related mediators, is known to be associated with tumour cell growth, while normal cells exhibit active PKR. Furthermore, wild type cells exposed to viral infection exhibit elevated PKR expression which results in the suppression of viral replication, while cells that exhibit reduced, or no, PKR activity are susceptible to viral attack and exhibit cancerous growth. Similarly, the PML gene product functions as a tumour suppressor and it is also known to suppress viral replication.

By "differential susceptibility", it is meant a property associated with a cell that results in both tumour cell growth and the inability of the cell to suppress viral replication. Cells exhibiting differential susceptibility are preferred candidates for treatment of tumorous cell growth using the cancer therapeutic of the present invention. This differential susceptibility may be accentuated through the addition of one or more chemical agents prior to or during treatment of the tumour cell. Preferably, this chemical agent increases the resistance of a wild-type cell to viral



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infection, but has little or no effect on the response of a tumour cell to viral infection. An example, which is not to be considered limiting in any manner, of such a chemical agent is interferon.

5 By "PKR" it is meant a serine/threonine kinase that exhibits multiple functions including roles in the control of mRNA translation and gene transcription (1,2). The kinase harbors two double-stranded RNA dsRNA binding motifs in its amino terminal regulatory half and catalytic kinase domain in its carboxyl tail. Binding of dsRNA to the amino terminus induces a conformational change in the enzyme revealing and  
10 activating the catalytic kinase domain. The expression of PKR is induced by several PKR-mediators, including but not limited to, interferon.

By "PKR-mediator" it is meant proteins or compounds that directly, or indirectly affect PKR activity either at the gene or protein level and include both PKR-  
15 activators and PKR-inhibitors. Examples of PKR-activators include, but are not limited to STAT1 (see Figure 1), Interferon regulatory factor (IRF-1), and interferon. Examples of PKR-inhibitors, include, but are not limited to, VA RNAs, p58(IPK), factors associated with the Ras pathway, the ribosomal protein L18, or proteases that degrade PKR protein. PKR activity may also be mediated through mutations to the  
20 gene encoding PKR, or to the regulatory region that drives the expression of *PKR*. These mutations may either increase or decrease PKR activity. Mutations to PKR that reduce PKR activity include, but are not limited to, the loss of dsRNA binding ability of PKR, or mutations that result in negative catalytic mutants. Mutations that increase PKR activity include, but are not limited to over-expression of PKR, or mutations that  
25 resulted in a more active PKR protein.

PKR regulates translation through the phosphorylation of eIF-2 $\alpha$ , a factor involved in the initiation of protein translation. Once phosphorylated, eIF-2 $\alpha$ -GDP, forms an inactive complex with eIF-2B resulting in a rapid inhibition of protein  
30 synthesis. PKR impinges on gene transcription indirectly via activation of NF $\kappa$ B. This activation appears to be carried out by PKR phosphorylation of an I $\kappa$ B kinase (3) which in turn phosphorylates I $\kappa$ B leading to its targeted destruction.



## PKR Antiviral activity

5

Infection of a cell by many distinct virus types leads to the formation of dsRNA (e.g. as replicative intermediates) resulting in the activation of PKR and its subsequent downstream effectors (see Figure 1). In particular, protein synthesis is rapidly terminated and an apoptotic cascade is initiated (4,5). As a result of the  
10 activation of PKR, the production of new virions is curtailed and the spread of virus through the organism is limited. Der et al (12) report a requirement for PKR in the induction of cellular apoptosis in response to a variety of stress inducers.

Without being bound by theory, it is possible that malignancies arise as a  
15 result of multiple mutations in genes that control cell proliferation and apoptosis. PKR's role in regulating protein synthesis coupled with its antiproliferative and pro-apoptotic properties make it a target for oncogenic mutations, which directly or indirectly affect its activity.

20 As described in more detail in the examples an initial screen of several viruses using PKR  $-/-$  animals indicated that PKR null animals are susceptible to infection by Vesicular stomatitis virus (VSV). Similar results were obtained *in vitro*, where VSV infection proceeded more rapidly in PKR  $-/-$  fibroblasts, when compared to infection in PKR  $+/+$  fibroblasts. These results demonstrate that PKR is required by mammalian  
25 cells to resist infections by VSV. Furthermore, certain cell lines, for example, but not limited to primary human bone marrow, were resistant to VSV infection, while leukemia cell lines were susceptible to VSV infection.

It is contemplated that viruses related to VSV, or other viruses that exhibit  
30 similar mechanisms of viral infection can be identified that exhibit the property of selectively infecting cells with reduced or no PKR activity. One of skill in the art can readily screen other viruses using the methods as described herein, for their ability to



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reduce the viability of cells, or kill cells lacking PKR activity, or PKR<sup>-/-</sup> cells, PKR<sup>-/-</sup> animals, or both PKR<sup>-/-</sup> cells and animals.

As indicated in the examples below, pretreatment of cells with interferon  
5 reduces virus infectivity by several orders of magnitude. Without wishing to be bound by theory, the addition of interferon may upregulate PKR expression resulting in this increased resistance to viral infection.

Because of its potent antiviral activity, viruses have evolved strategies to  
10 circumvent PKR. For example, HIV and Hepatitis C encode proteins dedicated to the binding and inactivation of PKR (6,7). Adenovirus encodes small RNA molecules (VA RNAs) which bind to but do not activate PKR (8). Influenza virus usurps a cellular protein p58(IPK) to inhibit PKR while polio virus initiates the proteolytic degradation of PKR (9,10). Large T antigen of SV-40 appears to function downstream  
15 of eIF-2 $\alpha$  to promote protein translation even in the presence of activated PKR (10).

#### PKR and Tumour Suppression

Expression of dominant negative PKR catalytic mutants in NIH 3T3 cells  
20 leads to their malignant transformation and facilitates their growth as tumours in nude mouse models (13,14). A similar phenomena has been observed using PKR mutants which have lost dsRNA binding activity. Induced expression of PKR in *S. cerevisiae* leads to growth arrest in the yeast—a phenomena that can be reversed by co-expression of a non-phosphorylatable version of eIF-2 $\alpha$ . Therefore, PKR has anti-proliferative  
25 activity and functions as a tumour suppressor.

There are several lines of evidence that PKR is inactivated, absent or reduced in expression in a broad spectrum of human malignancies:

- 30 • Oncogenic Ras mutations occur in about 30% of all human tumours while mutations in upstream Ras activators ( ie EGF receptor, Neu receptor, PDGF receptor) are even more common. Mundschau and Faller (15,16) have



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described an oncogenic Ras induced PKR inhibitor. Furthermore, Strong et al (17) demonstrated that activation of the Ras pathway results in down regulation of PKR activity.

- 5       • The ribosomal protein L18 is overexpressed in primary colorectal cancer tissues and has recently been shown to bind to and inactivate PKR (18).
- Patients with 5q translocations exhibit diminished PKR expression (19-21). Interferon regulatory factor 1 (IRF-1) is a transcription factor with tumour  
10       suppressor activity, which maps to the human chromosomal region 5q. PKR gene transcription is regulated in part by IRF-1.
- Human PKR maps to 2p21-22 and has been recently identified as the site of translocation in a case of acute myelogenous leukemia .
- 15       • In biopsies from poorly differentiated, highly malignant tumours, PKR protein was present at very low levels or was undetectable (23-25).

## STAT1

20

STAT1 is an essential mediator of the interferon pathway and its activation results in an upregulation of PKR mRNA and protein (see figure 1).

25       There is marked deficiency in the level/activity of STAT1 protein in interferon resistant melanoma cell lines and primary melanoma biopsy material (26), in a variety of human tumour cell lines including a myeloid leukemia, cervical carcinomas, ovarian cancer, and a lung carcinoma (27), and in a gastric adenocarcinoma (28,29). Furthermore, cutaneous T cell lymphoma (CTCL) is a malignancy which in general is responsive to interferon (however frequently clinical resistance arises in a substantial  
30       portion of cases). Sun et al (30) have reported that STAT1 protein is absent in a CTCL cell line suggesting that development of clinical resistance to interferon may arise due to STAT1 mutations.



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### PML: Promyelocytic Leukemia Gene

PML is an interferon induced gene that normally functions as a tumour suppressor and a key regulator of Fas, TNF $\alpha$  and interferon induced apoptosis. Recently, Chelbi-Alix et al have shown that another normal function of the PML gene product is to suppress virus replication. The PML-RAR fusion protein functions as a dominant negative inhibitor of interferon induced apoptosis and we would predict will also make APL cells preferentially susceptible to virus infection.

Down regulation of PKR protein or activity occurs in a broad spectrum of human malignancies. While cancer cells have attained a growth advantage and unbridled protein translation capacity by eliminating PKR or PKR-mediators, these cells have simultaneously eliminated one of the cell's primary and potent antiviral defence mechanisms. Therefore, tumour cells with reduced PKR activity will be more susceptible to infection than their normal counterparts. As indicated above, other components (e.g. STAT1 and PML) of the interferon pathway are frequently mutated in human malignancies, and loss of their activity will render tumour cells sensitive to virus infection. This differential susceptibility forms the basis for the use of viral-based cancer therapeutics of the present invention for the treatment of tumorous cell growth.

Screening of PKR null mouse strains with several different viruses indicated that PKR null animals are capable of suppressing a number of virus infections including vaccinia, influenza and EMCV. However, Vesicular Stomatitis Virus (VSV) exhibited an ability to infect PKR $-/-$  animals. VSV, a member of the Rhabdovirus family, was observed to kill 100% of PKR null animals following intranasal infection by as little as 50 infectious virus particles (or plaque forming units, pfu). In contrast, over 20,000 times as many VSV particles were required to kill half of infected wild type littermates.



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VSV is an enveloped, negative sense RNA virus with a simple five gene genome. This is a very well characterized virus family with several serologically distinct laboratory strains and a multitude of characterized mutants. The natural hosts of VSV include insects, rodents and domestic farm animals. In general, very few  
5 North Americans have come in contact with the virus – most human infections occurring in laboratory personnel and farmers. In humans infections are either asymptomatic or manifested as mild “flu”. There are no reported cases of severe illness or death amongst infected humans.

10 The ability of VSV to selectively infect tumour cells over wild-type cells was also observed. Tumour cell lines, following an overnight infection exhibited a 100 to 1000 times higher rate of infection than that detected in normal primary fibroblasts. Furthermore, the cytopathic effect (cpe) was accelerated in the tumour cell cultures.

15 Since PKR is an interferon inducible gene product, pretreatment of cells with interferon prior to exposure to VSV was tested to determined the effect of viral infection. Wild-type cell cultures, that were pretreated with interferon, were resistant to VSV infection, while tumour cell lines, for example, but not limited to, fibrosarcoma, melanoma, prostate carcinoma, leukaemia and ovarian sarcoma, were  
20 susceptible to virus infection (see Table 1, Example 2; Figure 2). Lung carcinoma cells (LC80) were also susceptible to VSV infection in the presence and absence of interferon (data not presented). However, several tumour cell lines were resistant to VSV infection in the presence of interferon.

25 Ovarian carcinoma cells, fibrosarcoma, lung carcinoma, melanoma, prostate carcinoma, lung carcinoma, and leukaemia cells are VSV sensitive, and this sensitivity was maintained in the presence of interferon, therefore, such tumor cells and cancers derived therefrom may be particularly amenable to VSV treatment. However, other cancers may also be amenable to viral treatment as described herein.  
30 Studies with respect to VSV sensitivity using primary tumour material is readily available in ascites fluid. Further, since the tumour is contained within the peritoneal cavity it may prove particularly suited to localized administration of a virally based



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therapeutic. In this regard, live tissue from patient's ascitic fluid can be tested for the ability of the tumour cells to support VSV infection in the presence and absence of interferon.

5           It is expected that VSV will have therapeutic activity *in vivo*, and will have the ability to kill distant (metastatic) tumour growths. To date no significant organ pathology in treated mice have been observed, however, the kinetics of VSV viremia need to be further studied. Nude mice, implanted with human melanoma cells received VSV, or additional melanoma cells infected *in vitro* with VSV (see Example  
10 5), to ensure the continuous production of infective particles to the tumour over a several hour period, via injection (Figure 5). In mock-injected animals (VSV(-); injection with vehicle alone) tumours grew continuously over the course of the experiment. Animals which received only pure virus showed initially continuous growth of tumours over the first four day period, after this time the tumours began to  
15 reduce in size and continued to do so over the course of this experiment. Tumours that were injected with infected cells stopped growing and regressed to small hard nodules resembling scar tissue. In some of the larger injected tumours, ulcers formed on the tumour within 1-2 days, (see Figure 6). While both injection of purified virus and infected melanoma cells caused significant regressions, infected producer cells were  
20 more effective.

          Studies with an immunocompetent mouse tumour model (i.e. as described by Strong et al; 17) will examine the affects of antibody response to therapeutic VSV infection, and determine if VSV infection of tumour cells increases their  
25 immunogenicity and promotes recognition of tumour antigens by the host organism.

          Primary human bone marrow was also found to be resistant to VSV infection in the absence of interferon pretreatment (see Table 1, Example 2), indicating that these cells have an innate resistance to VSV infection. In contrast two leukemia cell  
30 lines (M07E and L1210) were also tested and found to be susceptible to VSV infection as evidenced by cytopathic effect, virus growth and loss of cell viability.



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While the results disclosed herein relate to VSV, it is to be understood that one of skill in the art, by following the methods outlined in this document, will be readily able to screen other VSV strains, derivatives of VSV including mutants of VSV, or related viruses for the ability to selectively kill tumour cells. There are several other serologically and biologically distinct strains of VSV, which can be tested for this property. Such VSV strains include, but are not limited to New Jersey, Piry, Coccal, and Chandipura. Identification of other suitable serologically unrelated strains may be useful if sequential VSV injections are required to completely eradicate tumours. Furthermore, picornaviruses (eg rhinoviruses) are known to be relatively innocuous to normal human tissues yet grow extremely well in transformed cells in tissue culture, and these viruses may also be used. Furthermore, combinations of viruses may be used to enhance the cytopathic effect observed with VSV.

In order to determine whether the presence of either a normal or tumor cell could affect the other cell type (either normal and tumor cell) and alter the resistance or susceptibility of either of these cells to VSV infection, normal cells and fibroblasts were co-cultured in the presence of VSV. The culture was infected at an moi of 0.1 pfu/cell and the infection allowed to proceed in the presence or absence of interferon. At 0, 12 and 24 hours (Figure 4) the cultures were fixed and stained with antibodies to large T antigen (red nuclei) to detect the 293T cells and with DAPI (blue nuclei) which stains all cell types (Figure 4). The number of 293T cells (red nuclei) steadily declined during the time course and displayed severely condensed or fragmented nuclei characteristic of a cell dying from virally induced apoptosis. This selective destruction of the transformed cells was seen both in the presence and absence of interferon. The normal fibroblasts did not develop nuclear changes nor were their numbers reduced in response to VSV infection even though 293T cells were producing copious amounts of virus within the co-culture. This indicates that mixtures of cell populations may be treated with VSV while still maintaining tumor cell sensitivity, and normal cell resistance to VSV.

30

In addition there are a number of mutants of VSV, for example, but not limited to mutants which are impaired in the shut down of host protein synthesis or are more



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or less sensitive to interferon, which may exhibit differential infection between normal and tumour cells. For example, which is not intended to be limiting in any manner, other viral mutants are known which show tropism for STAT1 or PKR negative cells include an influenza virus strain which is unable to inactivate PKR has been described  
5 (36) Adenovirus mutants which lack the PKR inactivating VA gene are known to grow better in the absence of PKR.

As described herein, VSV mutants were isolated that grew poorly on interferon responsive cells. These mutants were selected based upon their ability to  
10 form small plaques in monolayers of interferon-responsive cells. On interferon non-responsive cells (i.e. tumor cells) these mutants form large plaques. The selection of mutants by size of plaque in interferon-responsive cells allows for the isolation of virus that grows poorly in normal cells. However, other VSV mutants may be obtained under different selection criteria. Mutants isolated using interferon-  
15 responsive cells were amplified and tested for their ability to kill tumour and normal cells. The rationale here is that VSV mutants, which can induce interferon in target cells, would limit their own replication in an interferon responsive cell population. These same viruses would however have unrestricted growth in tumour cells that lack interferon responsiveness. These mutants are of value, as they have even less  
20 cytopathic effect on normal tissues while maintaining oncolytic activity than wild type VSV.

Four mutants (Mut 1-4) were obtained based on their ability to form plaques in monolayers of interferon-responsive cells. These mutants, and wild type virus (moi of  
25 1.0 pfu/cell) were used to infect melanoma cells and normal human foreskin fibroblasts. All of the mutants were able to kill tumour cells efficiently but normal cells infected with the mutants even after long periods of infection appeared completely uninfected. At this same moi wild type VSV demonstrated a cytopathic effect on the normal cells. These results indicate that the mutant virus have a greater  
30 therapeutic effect in that they kill tumour cells efficiently while sparing normal cells, and that they also have the ability to produce more virus particles and increase virus spread throughout the tumour (see Example 4). Surprisingly these mutants grew more



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rapidly than wild type VSV (Indiana) in HCT 116 colon carcinoma cells but not in OSF7 cells (See Example 21 and Figures 10A and 10B). VSV mutants that display rapid growth in the tumour cell of interest but not in normal cells are preferred.

5           Earlier experiments indicated that PKR  $-/-$  mice were killed with VSV by several routes of infection, however, these mice were not affected by intravenous injections of the virus. In order to determine whether plasma components were inactivating the virus upon contact, VSV produced from several sources including within mouse L cells was incubated with human serum (from normal uninfected  
10   donor) and the virus titer after incubation determined (Example 6). The viral titer of L cell-produced VSV dropped four hundred fold, while VSV produced in human melanoma cells was unaffected by incubation in plasma. These results indicate that the choice of cell line for the production of VSV is critical. Based on this observation it is possible to screen human cell lines for those that produce optimum amounts of  
15   virus that is not sensitive to human serum.

Without wishing to be bound by theory, it may be that the difference in these two virus preparations reflects the nature of the cohort of proteins found on the surface of the virus producing cells. As part of its replicative cycle, VSV buds through  
20   the plasma membrane and acquires cellular protein on its envelope. Certain proteins found on L cells when expressed in the context of the virus particle could activate complement. Indeed, it has been shown earlier that retrovirus particles produced in certain mouse cells are inactivated by serum while the same virus produced in a subset of human cell lines was unaffected by plasma. (Pensiero, M.N., et al. Hum Gene  
25   Ther, 1996. 7:1095-1101).

Conventional techniques for VSV production are difficult to scale up for industrial production. Therefore, the purification of VSV, using an affinity matrix, for example affinity chromatography was explored. (See Example 7). However, other  
30   protocols for affinity purification may also be used as known within the art, for example, but not limited to, batch processing a solution of virus and affinity matrix, pelleting the VSV-bound matrix by centrifugation, and isolating the virus. In order to



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provide the virus with an affinity tag to be used for the purification of the virus, the virus may be genetically modified, using techniques well known in the art, to express one or more affinity tags on its surface, preferably as a fusion viral envelope protein, or producer cell lines may be engineered to express one or more affinity tags on their plasma membranes which would be acquired by the virus as it buds through membrane, however, endogenous viral envelope proteins may also be used. One well characterized affinity tag involve the use of Histidine residues which binds to immobilized nickel columns, however, it is to be understood that other affinity tags may also be employed.

10

Cell lines can be prepared that act as a universal producer of VSV, or other virus, that expresses a chimeric VSV protein with nickel binding, or other affinity tag properties. This universal producer cell may be used for the production of a chimeric protein (affinity tag) for any enveloped virus (including all enveloped RNA and DNA viruses). For the purification of virus which bud through the nuclear membrane (such as Herpes virus), a tag to be expressed on the viral envelope protein expressed in the nuclear membrane is engineered.

15

Other affinity tags include antibodies, preferably an antibody which recognizes a particular peptide under conditions of low salt, low temperature or in the presence of a critical cation/anion. Physiological salt concentrations, thermal elution or chelation could effect elution. Antibodies generated against di or tripeptides may also be used for purification. In this manner, two or more of these tags on the surface of a single virus particle would allow for the sequential affinity purification of the virus.

20

25

VSV may be genetically modified in order alter its properties for use *in vivo*. Methods for the genetic modification of VSV are well established within the art. For example a reverse genetic system has been established for VSV (Roberts A. and J.K. Rose, Virology, 1998. 247:1-6) making it possible to alter the genetic properties of the virus. Furthermore, standard techniques well known to one of skill in the art may be used to genetically modify VSV and introduce desired genes within the VSV

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genome to produce recombinant VSVs (e.g. Sambrook *et al.*, 1989, A Laboratory Manual. New York: Cold Spring Harbor Laboratory Press).

5 VSV may be targeted to a desired site *in vivo* to increase viral efficacy. For example, modification of VSV G protein to produce fusions that target specific sites may be used to enhance VSV efficiency *in vivo*. However, it is to be understood that other protein targets in addition to the VSV G protein may also be modified to produce such fusion proteins. Such fusion proteins may comprise, for example, but not limited to, Single chain Fv fragments (Lorimer, I.A., et al. Proc. Natl. Acad. Sci. U.S.A., 1996. 93:14815-20) that have specificity for tumour antigens. An example of  
10 such a single chain Fv fragment that may be used to prepared a VSV G fusion protein, is an Fv fragment that targets a mutant EGF receptor found on about 80% of human breast tumour cells.

15 VSV may also be modified to express one or more suicide genes capable of metabolizing a pro-drug into a toxic metabolite thereby permitting VSV infected cells to be killed by administration of a pro-drug. For example, VSV comprising the herpes virus thymidine kinase gene or the cytosine deaminase gene encodes an enzyme that can convert ganciclovir or 5-FC, respectively, into a toxic compound. However, it is  
20 to be understood that other suicide genes may also be employed. As it is well established that ganciclovir metabolites kill not only cell expressing HSV TK but also cells in the immediate vicinity, rVSV comprising these suicide genes exhibit several advantages. For example, the effective killing by the virus is increased since one infected cell kills ten or more surrounding tumour cells, furthermore rVSV  
25 comprising a suicide gene permits the elimination of virus if desired from an individual infected with the virus. This may be important in situations where it is unclear how VSV may affect an individual. For instance, an immune comprised individual may be unexpectedly susceptible to VSV. Thus the addition of a suicide gene would be an improvement on the safety of the viral therapeutic.

30

VSV may also be modified by the introduction of a mammalian gene product. Such a mammalian gene product would limit VSV growth in normal cells, but not the



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growth of VSV in tumour or diseased cells. For example, rVSV capable of expressing one or more transactivators of p53, activates apoptotic pathways in normal cells but not tumor cells. Such rVSVs therefore selectively limit virus spread in normal tissues. However, it is to be understood that other mammalian gene products may also be expressed within VSV for this purpose. Another example, which is not to be considered limiting in any manner is the PKR gene. A rVSV expressing the PKR gene limits virus replication in all normal cells, however, in cells that express PKR inhibitors, the virally encoded PKR is inactivated. An example of a cell that expresses one or more PKR inhibitors is a chronically Hepatitis C infected cell. Since Hepatitis C encodes and expresses two known inhibitors of PKR (i.e. NS5A and E2), a VSV encoded PKR gene product is be neutralized, and VSV allowed to replicate freely.

The above description is not intended to limit the claimed invention in any manner, furthermore, the discussed combination of features might not be absolutely necessary for the inventive solution.

The present invention will be further illustrated in the following examples. However it is to be understood that these examples are for illustrative purposes only, and should not be used to limit the scope of the present invention in any manner.

#### **Example 1: PKR negative cells are susceptible to VSV infection**

##### ***In vivo* experiments**

Initial studies were directed to identifying viruses that are capable of infecting PKR<sup>-/-</sup> animals and cells. Using homologous recombination strategies, PKR null mouse strains were generated (35, which is incorporated by reference) and tested for their ability to fight virus infections. Since these mice are PKR<sup>-/-</sup>, they should be susceptible to virus infection. Several species of virus were administered to PKR null animals over a range of concentrations.



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**Infection of PKR null mice:**

A PKR null mouse line was generated using conventional knockout technology (Abraham, N., et al., J Biol Chem, 1999. 274:5953-5962.). Groups of five female mice, 3 months of age or greater, were infected intranasally with varying amounts of vesicular stomatitis virus (Indiana strain). Age matched wild type animals were infected in parallel and both sets of animals were monitored on a daily basis for signs of infection. These include, hydration, piloerection, activity level, appetite, hind limb paralysis, respiratory rate, body weight and any other symptoms indicating that the animal was in distress.

Wild type animals showed few and only transient symptoms at multiplicities of infection up to  $10^5$  pfu with VSV. In contrast, PKR null animals very rapidly developed dehydration, piloerection, loss of appetite, rapid respiratory rate, decreased activity and squinting crusty eyes. At high doses of VSV infection ( $10^5$  pfu) the animals showed symptoms in less than 24 hours and usually succumbed to the infection within 48 hours. At doses of infection as low as 25 pfu, 100 percent of the PKR null animals died of VSV infection within 5 days. In separate experiments groups of five wild type and PKR null animals were sacrificed at 48 hours post infection with VSV and organs were removed to assess viral titres. In the PKR animals titres in excess of one million PFU / ml of lung homogenate were found at this time while in wild type animals virus titres ranged from 0 to 100 pfu per ml of lung homogenate. In the wild type and PKR null animals similar amounts of virus were found in the brain. The remainder of the tissues in both mouse strains had undetectable virus at this time post infection.

Vesicular stomatitis virus, a member of the Rhabdovirus family was able to kill 100% of PKR null animals following intranasal infection by as little as 50 infectious virus particles (or plaque forming units, pfu). In contrast, over 20,000 times as many VSV particles were required to kill half of infected normal littermates. These results indicate that PKR null animals are capable of suppressing a number of virus infections including vaccinia, influenza and EMCV. However, VSV exhibited



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an ability to infect PKR-/- animals. These results also indicate that PKR is required by mammalian cells to resist infections by VSV (Indiana laboratory strain).

## **Example 2: Selective killing of tumour cells with VSV**

### **5    *In vitro* experiments**

Several tumour cell lines were chosen at random from the Ottawa Regional Cancer Center and tested for their susceptibility to VSV infection. Primary fibroblast cultures from healthy adult volunteers or primary bone marrow samples from healthy  
10    donors were used as control cells.

### **Infection of tumour cells with VSV:**

As a first test of the oncolytic properties of VSV, virus production and  
15    cytopathic effect following an overnight incubation with VSV was assessed. Monolayers of cells were incubated with the Indiana strain of VSV at a multiplicity of infection (moi) of 0.1 plaque forming units (pfu). After allowing virus to adsorb for 30 minutes at 37 C, the cultures were rinsed thoroughly with phosphate buffered saline (PBS) and then cultured an additional 18 hours at 37 C. At this time, the  
20    cultures were examined microscopically for cytopathic effect (cpe) and photographed. The 18 hour supernatant was removed and virus titres per ml of medium determined. In some experiments, cultures were preincubated for 12 hours with human alpha interferon (100 units/ml) prior to infection.

25    To examine the kinetics of infection of the assorted cell types a modified cpe assay (Heise, C., et al., Nat Med, 1997. 3:639-645) was used. Essentially, monolayers of cells were infected at an moi of 0.1 pfu in a 12 well plate. At time 0 and every 12 hours subsequent up to 48 hours, one well of infected cells was fixed with 0.5 ml Leukostat fixative (Fisher Diagnostics) for 2 minutes. At the end of the experiment  
30    monolayers were stained with Leukostat stains 1 and 2 following manufacturers instructions. Since PKR is an interferon inducible gene product, the pretreatment with interferon, 100 units/ml of human alpha interferon 12 hours prior to infection, was



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tested to determine if interferon could enhance protection within the assorted cell cultures. The data are presented in Table 1 and Figures 2-3.

**TABLE 1: Cell lines tested for VSV sensitivity**

5

Cell line	cell type	Reference	Untreated Overnight Virus Yield	Interferon Overnight Virus Yield
OSF 16	human normal fibroblast	ORCC <sup>1</sup>	$1 \times 10^5$ pfu	0 pfu
AG1522	human foreskin fibroblast	[20]		0 pfu
OSF 7	human normal fibroblast	ORCC	$1 \times 10^6$	0 pfu
OSF 12	human normal fibroblast	ORCC	$2 \times 10^5$ pfu	0 pfu
MN11	mouse fibrosarcoma	[21]	$1 \times 10^8$	$1 \times 10^4$
A2780	human ovarian carcinoma	[22]	$2 \times 10^8$	$1 \times 10^7$
H-1078	normal human bone marrow	ORCC	0 pfu (moi 10 pfu)	Not determined
M07E	human leukemic cell line	[23]	$2 \times 10^6$ (moi 1.0 pfu)	Not determined
L1210	mouse leukemic cell line	[24]	$4 \times 10^6$	$2 \times 10^4$
SK-MEL3	human melanoma	[25]	Not determined: cpe assay positive	Not determined: cpe assay positive
LNCAP	human prostate carcinoma	[26]	Not determined: cpe assay positive	Not determined: cpe assay positive
293T	fibrosarcoma transformed with SV-40 Large T and Adeno E1A	[27]	$1 \times 10^8$	$8 \times 10^7$
OVCA 432		[28]	$1 \times 10^7$	0 pfu
C13	ovarian carcinoma	[29]	$1 \times 10^8$	$1 \times 10^5$
OVCA 3		[30]	$5 \times 10^7$	Not determined
COS	Large T transformed simian kidney cell line	[31]	$2 \times 10^8$	Not determined
HCT 116	colon carcinoma	[32]	Not determined: cpe assay positive	Not determined: cpe assay positive



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OVCA 420		[28]	$1 \times 10^8$	$3 \times 10^6$
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1 established at the ORCC from forearm biopsy.

From the data in Table 1 it can be seen that although normal human fibroblasts  
 5 can support viral replication, the amount of virus produced and the progression to cell  
 lysis was substantially delayed when compared to tumour cells. An even more  
 substantial difference in virus production was observed following pretreatment with  
 interferon. While normal human fibroblast monolayers were completely protected  
 from the cytolytic affect of VSV by interferon, tumour cells remained sensitive,  
 10 producing copious amounts of viral particles and rapidly undergoing cytolysis.

Other cells lines, including a lung carcinoma cell line (LC80) and a leukaemia  
 cell line, AML5 (acute myelogenous leukemia 5) cells were also found to be  
 effectively killed by VSV. In the case of AML5, at a moi of 1.0 pfu/ml cells were  
 15 completely killed within 24 hours, while at 0.0001 pfu/ml the cells were killed within  
 72 hours, further indicating the sensitivity of leukaemia cells to VSV.

As can be seen in Figure 2, monolayers of tumour cells were much more  
 rapidly destroyed by VSV infection as compared to normal human fibroblasts. The  
 20 human melanoma cell line SK-MEL3, the LNCaP prostate cancer cell line and the  
 ovarian carcinoma cell A2780 all showed substantial cpe as early as 12 hours post  
 infection. Although the normal human fibroblast cultures were infected and capable  
 of producing virus (see Table 1), the kinetics of infection was substantially slower  
 than in the three tumour cell lines tested in this experiment. In addition, as with the  
 25 overnight virus growth assay (Table 1, Figure 2), interferon alpha treatment  
 completely protected the normal human fibroblasts, but was ineffective at protecting  
 the three tumor cell lines from the cytopathic effect of VSV.

The results obtained for Table 1 demonstrate that a screening strategy for  
 30 determining the types of tumours which are susceptible to killing by VSV may be  
 employed using for example, but not limited to, the NIH/NCI standard panel of



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tumour cell lines available from ATCC. These cell lines are screened in order to determine the time to complete cpe and/or virus growth using various initial multiplicities of infection. These experiments are done in the presence and absence of interferon so that the number of and types of tumours that are VSV sensitive and are resistant to interferon's antiviral activity are determined.

### **VSV Treatment of Leukemia**

VSV does not productively infect bone marrow stem cells, even at high moi of 10 pfu/cell (H-1078; Table 1). The treated cultures retained all of their stem cell characteristics. Two leukemia cell lines (MO7E and L1210; Table 1) were killed following an overnight infection and produced large amounts of virus.

To determine whether VSV could kill primary leukemia cells from a cancer patient, a peripheral blood sample was obtained from an AML patient and white blood cells collected and plated in RPMI media plus 10% FBS ( $10^7$ /well in 6 well plate, each infection in duplicate). Cells were mock infected or infected at an moi of 10.0/cell. VSV selectively killed myeloid leukemic cells as indicated by the decrease in the percentage of blast cells (leukemic blasts), while the overall cell number was minimally affected (i.e. neutrophils flourished). The leukemic sample produced titres of VSV exceeding  $10^7$  pfu/ml at 16 hours post infection. The number of blast cells in the sample was dramatically reduced at 21 hours post infection while the proportion of normal neutrophils increased. Mock infected cells (-VSV) contained almost 70% blast cells in a monolayer, while in cells infected with VSV (+VSV) normal cells predominated. These results demonstrate VSV is able to preferentially kill primary leukemic blast cells while sparing normal blood cells.

### **Example 3: Killing of tumour cells in mixed cultures:**

Normal human fibroblasts and 293T tumour cells were co-cultured in a 50:50 mixture. Since 293T cells express the large T antigen which is not found in normal cells, the two cell types can be distinguished by immunofluoresence.



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In this experiment cultures were infected at an moi of 0.1 pfu/cell and the infection allowed to proceed in the presence or absence of interferon. At 0, 18 and 24 hours (Figure 4) the cultures were fixed and stained with antibodies to large T antigen (red nuclei) to detect the 293T cells and with DAPI (blue nuclei) which stains all cell types (Figure 4). Initially both cell types displayed a spindle-like morphology with large oval nuclei. After 18 hours the number of 293T cells (red nuclei) were reduced and many of the remaining 293T cells displayed altered nuclear morphology. By 24 hours post-infection very few 293T cells were detected and those few that remained displayed severely condensed or fragmented nuclei characteristic of a cell dying from virally induced apoptosis.

This selective destruction of the transformed cells was seen both in the presence and absence of interferon. The normal fibroblasts did not develop nuclear changes nor were their numbers reduced in response to VSV infection even though 293T cells were producing copious amounts of virus within the co-culture.

#### **Example 4: VSV Mutants as Oncolytic Agents:**

VSV mutants were isolated based upon their ability to form small plaques in monolayers of interferon-responsive cells, as compared to the size of plaques in monolayers of interferon-nonresponsive cells. Viral isolates, which form small plaques in interferon-responsive cells were picked, amplified and re-cloned. Mutants isolated in this way were amplified and tested for their ability to kill tumour and normal cells. The rationale here is that VSV mutants, which can induce interferon in target cells, would limit their own replication in an interferon responsive cell population. These same viruses would however have unrestricted growth in tumour cells that lack interferon responsiveness. These mutants would be of value, as they should have even less cytopathic effect on normal tissues while maintaining oncolytic activity.



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Four mutants (Mut 1-4) were obtained based on their ability to form small plaques in monolayers of interferon-responsive cells. These mutants were initially identified by Dr. Lauren Poliquin (University of Quebec at Montreal) and provided by him. After five rounds of plaque purification, these mutants and wild type virus (moi  
5 of 1.0 pfu/cell) were used to infect melanoma cells and normal human foreskin fibroblasts and titres of released virus determined 12 and 24 hours post infection.

All of the mutants were able to kill tumour cells efficiently but normal cells infected with the mutants even after long time points appeared completely uninfected.  
10 At this same moi wild type VSV demonstrated a cytopathic effect on the normal cells. It was also observed that all of the VSV mutants produced approximately ten times more virus than the wild type VSV following an overnight infection of melanoma cells. On normal cells, while the Mutants 1-4 had significantly less cytopathic effect than wild type VSV, similar amounts of virus were produced from the infected  
15 cultures. These results indicate that the mutant virus have a greater therapeutic effect in that they kill tumour cells efficiently while sparing normal cells, and that they also have the ability to produce more virus particles and increase virus spread throughout the tumour.

#### 20 **Example 5: Infection of Nude Mice Bearing Human Tumour Xenografts:**

Nude mice were implanted with human melanoma cells and divided into groups. One group received a mock injection (VSV(-)), and the other were injected with wild type VSV or injected with additional melanoma cells infected *in vitro* with  
25 VSV for one hour prior to injection into the tumour site in order to deliver cells that would continuously produce infective particles to the tumour over a several hour period (VSV(+)). The results of these experiments are seen in Figure 5 which shows the average of the tumour area with time in treated and mock injected animals.

30 In the case of mock-injected animals (VSV(-); injection with vehicle alone) tumours grew continuously over the course of the experiment. Animals which



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received only pure virus showed initially continuous growth of tumours although at day 4 post infection the tumours began to shrink and continued to do so over the course of this experiment. Tumours that were injected with infected cells demonstrated the most dramatic regressions. Essentially most tumours stopped  
5 growing and regressed to small hard nodules resembling scar tissue.

In some of the larger injected tumours, ulcers formed on the tumour within 1-2 days, (see Figure 6), followed by continuous shrinkage of the once rapidly growing malignancy. While both injection of purified virus and infected melanoma cells  
10 caused significant regressions, infected producer cells were more effective.

**Example 6: The choice of cell line for producing VSV affects sensitivity of the virus to plasma:**

15 Earlier experiments indicated that PKR  $-/-$  mice were killed with VSV by several routes of infection, however, these mice were not affected by intravenous injections of the virus. Without wishing to be bound by theory, this could be because the PKR  $-/-$  vascular endothelial cells provide a barrier to tissue infection or because plasma components were inactivating the virus upon contact. To test this latter idea  
20 VSV produced from several sources including within mouse L cells was incubated with human serum (from normal uninfected donor) and the virus titer after incubation determined.

Following incubation of VSV in human serum, the viral titer of L cell-  
25 produced VSV dropped four hundred fold. On the on the other hand VSV produced in human melanoma cells was unaffected by incubation in plasma.



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These results indicate that the choice of cell line for the production of VSV is critical. Based on this observation it is possible to screen human cell lines for those that produce optimum amounts of virus that is not sensitive to human serum.

## 5     **Example 7: Strategy for VSV concentration and purification**

Conventional techniques for VSV production include centrifugation steps and gradient purification - both of these approaches difficult to scale up for industrial production. Therefore, alternate protocols for the purification of VSV, for example  
10     affinity columns for the simultaneous concentration and purification of virus particles has been explored.

In order to provide the virus with an affinity tag to be used for the purification of the virus, endogenous proteins may be used or, the virus may be engineered to  
15     express one or more affinity tags on its surface, or producer cell lines may be engineered to express one or more affinity tags on their plasma membranes which would be acquired by the virus as it buds through membrane. The unique viral envelope proteins can be purified using affinity chromatography.

20     One such affinity tag may involve the use of Histidine residues which binds to immobilized nickel columns, however, it is to be understood that other affinity tags may also be employed. This approach has been tested using the bacterial virus M13. Using a phage peptide display system (Koivunen, E., et al., J. Nucl Med, 1999. 40:883-888), viral particles expressing Histidine containing peptides which bind to  
25     nickel columns, but that can be eluted with imidazole, were selected including:

CTTHRHTSNC (SEQ ID NO:1); CLNAHRTTHHHC (SEQ ID NO:2);  
CHGLHSNMRHC (SEQ ID NO:3); CHHHHRLNC (SEQ ID NO:4); CHSHHHRGC  
(SEQ ID NO:5); CWDHHNHHC (SEQ ID NO:6); CDNNHHHHC (SEQ ID NO:7);  
CHHHRISSHC (SEQ ID NO:8). The expression of these peptides on the surface of



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M13 phage resulted in the purification concentration of the virus on nickel resins and their elution using low concentrations of imidazole.

5 One or more of these sequences can be integrated into the VSV G protein to result in an increased concentration of the viral particles bearing these peptides on nickel residues. The eluted virus is expected to retain its infectivity.

10 In this manner a cell line that can be a universal producer of VSV, or other virus, that expresses a chimeric VSV protein with nickel binding properties is produced. This universal producer cell may be used for the production of such a chimeric protein (affinity tag) for any enveloped virus (including all enveloped RNA and DNA viruses). For the purification of virus which bud through the nuclear membrane (such as Herpes virus), a tag to be expressed on the viral envelope protein expressed in the nuclear membrane is engineered.

15

Other affinity tags include antibodies, preferably an antibody which recognizes a particular peptide under conditions of low salt, low temperature or in the presence of a critical cation/anion. Physiological salt concentrations, thermal elution or chelation could effect elution. Antibodies generated against di or tripeptides may also be used  
20 for for purification. In this manner, two or more of these tags on the surface of a single virus particle would allow for the sequential affinity purification of the virus.

### **Example 8: Use of VSV to treat chronic infections**

25 Some human disorders arise as a result of chronic viral infections including latent herpes infection, hepatitis, AIDS and cervical cancer. In each of these cases, the causative viral agent has evolved mechanisms to inactivate components of the interferon response pathway including PKR (e.g. Chelbi-Alix, M.K. and H. de The, Oncogene, 1999. 18:935-941; Gale, M.J., Jr., et al., Virology, 1997. 230: 217-227;



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Gale, M.J., et al., Clin Diagn Virol, 1998. 10:157-162; Gale, M., Jr. and M.G. Katze, Methods, 1997. 11:383-401; Barnard, P. and N.A. McMillan, Virology, 1999.

259:305-313). Therefore, the administration of VSV, or interferon inducing VSV mutants, or a combination thereof, to individuals suffering from these disorders,

5 selectively ablates the chronically infected cells. Further therapeutic efficacy could be found by targeting through cell or viral receptors only the chronically infected cells.

### **Example 9: Genetic modification of VSV**

10 A reverse genetic system has been established for VSV (Roberts A. and J.K. Rose, Virology, 1998. 247:1-6) making it possible to alter the genetic properties of the virus.

#### Targeting VSV to desired sites *in vivo*

15 Presently VSV can bind to most mammalian cell types although its replication once inside the cell can be restricted (i.e. by interferon responsive gene products including PKR). Thus the effective dose of virus that can actually find target cells (i.e. tumour cells) for productive infection can be greatly limited simply by the "sink" that other normal tissues provide. Therefore, VSV may be genetically modified in  
20 order to bind and infect only tumour cells.

Recombinant DNA techniques well known in the art (e.g. Sambrook *et al.*, 1989, A Laboratory Manual. New York: Cold Spring Harbor Laboratory Press) are used to modify VSV G protein. Single chain Fv fragments (Lorimer, I.A., et al. Proc. Natl. Acad. Sci. U.S.A., 1996. 93:14815-20) that have specificity for tumour antigens  
25 are fused to VSV G protein. An example of such a single chain Fv fragment is one that targets the mutant EGF receptor that is found on about 80% of human breast tumour cells.



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Expression of suicide genes within VSV

The VSV genome is modified so that it comprises the herpes virus thymidine kinase gene or the cytosine deaminase gene. Both of these genes encode enzymes which can convert pro-drugs into toxic compounds (e.g. ganciclovir or 5-FC). Viruses  
5 modified in this way express these suicide genes, thereby permitting VSV infected cells to be killed by administration of the pro-drug. This provides two advantages since(1) it is well established that ganciclovir metabolites kill not only cell expressing HSV TK but also can cells in the immediate vicinity. This "by-stander effect" can increase the effective killing by the virus (i.e. one infected cell could result in the  
10 killing of ten or more surrounding tumour cells); and (2) having a VSV with a suicide gene could allow the elimination of virus if desired from an individual infected with the virus.

Controlling VSV growth *in vivo*

15

A mammalian gene product is introduced within VSV to limit VSV growth in normal cells, but this gene product does not affect VSV growth in tumour or diseased cells.

20

Recombinant VSVs (rVSV) comprising one or more transactivators of p53, activate apoptotic pathways in normal cells but not tumour cells. Such rVSVs limit virus spread in normal tissues but allow virus growth in tumour cells.

25

rVSV comprising the PKR gene limits virus replication in all normal cells, however, in cells that express PKR inhibitors, the virally encoded PKR is inactivated. An example of a cell that expresses one or more PKR inhibitors is a chronically Hepatitis C infected cell. Since Hepatitis C encodes and expresses two known inhibitors of PKR (i.e. NS5A and E2), a VSV encoded PKR gene product is be neutralized, and VSV allowed to replicate freely.



**Example 10. Progressive loss of interferon responsiveness with oncogenic transformation**

5 Murine fibroblasts at various stages of transformation, either pretreated with 100 units of interferon alpha or left untreated, were infected with WT Indiana VSV at an MOI of 0.1 pfu/cell. Viral production was measured 18 hours pi by standard plaque assay. MEF: mouse fibroblast primary cultures isolated from Balb/C mouse embryos. NIH 3T3 cells: immortalized mouse embryo fibroblasts. PVSrc: NIH 3T3  
10 cells transformed with the viral src gene. MOP 8: NIH 3T3 cells transformed with the polyoma virus Large T antigen. Results are shown in Table 2.

In this example, loss of interferon responsiveness correlates with susceptibility to VSV infection and progression of the malignant phenotype. The MEF cells are mortal (ie have a limited lifespan in culture) and completely interferon responsive.  
15 NIH 3T3 cells although not tumourigenic are immortalized and are about ten thousand fold less responsive to interferon than MEFs. The PVSrc and MOP 8 cells are fully tumourigenic, support robust VSV replication and are minimally protected by interferon treatment.

20 **TABLE 2**

Cell Line	Viral Titre (pfu/ml)	
	Untreated	IFN- $\alpha$
25 MEF (Mouse Embryonic Fibroblast)	$4 \times 10^6$	<10
NIH3T3	$8 \times 10^7$	$1 \times 10^4$
PVSrc	$3 \times 10^9$	$2 \times 10^7$
MOP 8	$1 \times 10^8$	$5 \times 10^6$



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**Example 11. Virus yield after overnight infection of various cell lines either untreated or treated with IFN**

A variety of normal and transformed cell lines were either untreated or pre-treated with 100 units of IFN- $\alpha$ , infected at an MOI of 0.1 pfu/ml with WT Indiana VSV and incubated for 18 hours at 37 °C. Culture media from each sample was titred for VSV production. Results are shown in Table 3.

This example demonstrates that viral production is ten to ten thousand times more efficient in a range of tumour cell types as compared to normal primary tissues. In the presence of interferon alpha, virus production in normal primary cells is almost completely blocked while in tumour cells interferon has little or no effect on VSV replication.

**TABLE 3**

Cell Line	Viral Titre (pfu/ml)	
	Untreated	IFN- $\alpha$
OSF7 (primary normal human fibroblast)	$1 \times 10^6$	<10
OSF12 (primary normal human fibroblast)	$2 \times 10^5$	<10
OSF16 (primary normal human fibroblast)	$1 \times 10^5$	<10
PrEC (primary normal human prostate epithelium)	$8 \times 10^6$	<10
HOSE (primary normal human ovarian surface epithelium)	$1 \times 10^7$	<1000
A2780 (human ovarian carcinoma)	$2 \times 10^8$	$1 \times 10^7$
OVCA 420 (human ovarian carcinoma)	$1 \times 10^8$	$3 \times 10^6$
C13 (human ovarian carcinoma)	$1 \times 10^8$	$1 \times 10^5$
LC80 (human lung carcinoma)	$2 \times 10^9$	$6 \times 10^7$
SK-MEL3 (human melanoma)	$1 \times 10^9$	$1 \times 10^9$
LNCAP (human prostate carcinoma)	$4 \times 10^9$	$5 \times 10^9$
HCT116 (human colon carcinoma)	$1 \times 10^9$	$2 \times 10^9$
293T (HEK cells transformed with T antigen and Ad virus E1A)	$1 \times 10^8$	$8 \times 10^7$



**Example 12. LD<sub>50</sub> for WT and mutant VSV delivered intranasally to PKR<sup>+/-</sup> (129xBalb/c) mice.**

5           8-10 week old female mice were anaesthetised and infected intranasally with virus diluted in 50 µl of phosphate buffered saline (PBS) into the nares of each animal (PKR<sup>+/-</sup> ; 129 x Balb/c strain). Lethal dose 50 values were calculated using the Korler-Spearman method. Results are shown in Table 4.

10           This example demonstrates that mutants I, II and III in particular, are attenuated as compared to the wild type Indiana strain of virus when tested for toxicity in 129 X Balb/c mice.

**TABLE 4**

15

<b>Virus</b>	<b>Intranasal LD<sub>50</sub> (pfu)</b>
WT Indiana	1 x 10 <sup>4</sup>
Mutant I	1 x 10 <sup>10</sup>
20   Mutant II	>1 x 10 <sup>10</sup>
Mutant III	3 x 10 <sup>8</sup>
Mutant IV	<1 x 10 <sup>5</sup>

25

**Example 13. PKR<sup>-/-</sup> mice are exquisitely sensitive to VSV compared to various PKR<sup>+/+</sup> mouse strains.**

30           PKR<sup>-/-</sup> and PKR<sup>+/+</sup> mice were infected intranasally at various doses and their survival monitored over time. All PKR<sup>-/-</sup> mice succumbed to the infection between days 2 and 5 depending on the dose, while control mice remained alive beyond this point. Results are shown in Table 5.

This example demonstrates the importance of the PKR gene product in the



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resistance of mice to VSV infection.

**TABLE 5**

		<b>Genetic Background</b>	<b>IN Dose (pfu)</b>	<b>Survival at day 5</b>
5		PKR <sup>+/+</sup>		
		Balb/c	5x10 <sup>4</sup>	5/5
		CD-1	5x10 <sup>4</sup>	5/5
		Balb/c x 129	5x10 <sup>4</sup>	5/5
10		PKR <sup>-/-</sup>		
		Balb/c x 129	5x10 <sup>4</sup>	0/5
			5x10 <sup>3</sup>	0/4
			5x10 <sup>2</sup>	0/3
			5x10 <sup>1</sup>	0/3

15

**Example 14. AML3 cells die by apoptosis following infection with VSV**

20           OCI/AML3 (acute myelogenous leukemia) cells were infected with VSV at an  
MOI of 3.0 pfu/cell . Fourteen and twenty hours post-infection unfixed samples were  
analyzed. Apoptotic cells with phosphatidylserine membrane translocation were  
detected by flow cytometry using Annexin-V-Biotin-X/NeutrAvidin-PE red  
fluorescent protein (Molecular Probes). Mitochondrial membrane depolarization in  
25   early apoptotic cells were analyzed by flow cytometry using JC-1 potential-sensitive  
dye (Molecular Probes). JC-1 is accumulated by polarized mitochondria shifting  
fluorescence emission from green to red spectra. Non-viable AML3 cells were  
identified using Ethidium (EthD-1) homodimer-1 red fluorescent vital dye (Molecular  
probes). Assays were performed following the manufacturers specifications. Results  
30   are shown in Table 6.

This example demonstrates that VSV kills AML cells at least in part through a  
virally induced apoptotic pathway.



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TABLE 6

	Tests		MOI 0.0	MOI 3.0	Net <sup>5</sup> Positive (Dead)
			Percent Positive	Percent Positive	
<b>14 hrs</b>					
<b>p.i.</b>	EthD-1		6.6	32.3	<sup>10</sup> 25.7
	Annexin V		14.3	52.7	38.4
	JC-1		7.5	21.4	13.4
					15
<b>20 hrs</b>					
<b>p.i.</b>	EthD-1 positive		6.4	58.5	52.1
	Annexin-V positive		10.8	79.6	<sup>68.8</sup> <sup>20</sup>
	JC-1		3.9	43.2	39.3

**Example 15: Mutant VSV strains infect and kill AML cells**

25

OCI/AML3 (acute myelogenous leukemia) cells were infected at an MOI of 1.0 and incubated for 23 hours. Unfixed cells were stained with Eth-D1 (ethidium dimer, Molecular Probes) to detect non-viable cells following manufacturers specifications. Number of stained cells per 10,000 counted used to calculate percent dead. Results are shown in Table 7.

30

This example demonstrates that the mutant VSV strains used are as effective as the wild type Indiana strain in killing AML cells.



**TABLE 7**

	Mock	WT IND	Mut I	Mut II	Mut III	Mut IV	Mut V
Percent Dead	30.0	64.7	60.7	86.7	72.1	74.4	82.8

5

**Example 16. VSV and VSV infected cells exhibit antitumor activity against human melanoma xenografts in nude mice.**

10 SK-MEL 3 (melanoma) derived tumours were developed in 8-10 week old female Balb/c athymic mice. On day 0, tumours were either left untreated or were infected with  $10^8$  pfu WT Indiana VSV in culture media or  $2.5 \times 10^6$  WT Indiana VSV infected SK-MEL 3 cells (VSV producing cells). Statistical differences were calculated between treated and untreated groups at each data point with the following  
 15 confidence values (b:  $p < 0.01$ ; c:  $p < 0.001$ ; d:  $p = 0.007$ ). Results are shown in Figure 7. On day 3, only tumours treated with VSV producing cells were significantly smaller than untreated tumours (a:  $p < 0.001$ ). No statistically significant differences in tumour volumes between groups were apparent from day 0 to day 2. Data points represent means  $\pm$  SEM from multiple tumours (untreated  $n=8$ ; VSV producing cells  
 20  $n=8$ ; VSV alone  $n=4$ ).

This example demonstrates that a single injection of VSV, directly into solid tumours profoundly affects tumour growth resulting in partial to complete regression. The use of infected tumour cells as a vehicle to deliver virus is also efficacious.

25

**Example 17: PKR<sup>-/-</sup> mice are acutely sensitive to intranasal VSV infection and demonstrate a deficiency in IFN mediated resistance.**

(A & B) PKR<sup>-/-</sup> and control mice (Balb/c X129) were infected intranasally with  $5 \times 10^4$  pfu of VSV and monitored for morbidity and survival over the course of  
 30 14 days, after which remaining animals were deemed to have survived the infection.



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Results are shown in Figures 8A and 8B.  $\text{PKR}^{-/-}$  mice showed a severe decrease in survival compared to control mice (WT), succumbing by day 3 or 4, while all control mice survived the infection.  $\text{IFN-}\alpha/\beta$  pretreatment (18 h prior to infection) with either  $2 \times 10^4$  IU (Fig. 8A) or  $2 \times 10^5$  IU (Fig. 8B) had no protective effect in  $\text{PKR}^{-/-}$  animals.

5           This example demonstrates that a single defect in the interferon pathway (absence of PKR gene product) is sufficient to render mice unable to resist VSV infections. This defect cannot be rescued by interferon.

10       **Example 18. Interferon can protect xenograft bearing nude mice during VSV treatment**

SK-MEL 3 melanoma cells were injected intradermally into CD-1 athymic nude mice. On day 0, tumours were injected with either live WT Indiana VSV ( $1 \times 10^9$  pfu) or an equivalent amount of UV inactivated VSV, and measured daily.

15       Results are shown in Figure 9. Interferon was administered to a subset of animals (VSV IFN) at the times indicated (black arrows). (UV-VSV n=4; VSV IFN n=6; VSV n=6). In these experiments a single intratumoural injection of VSV is tumour-inhibiting in all cases. All tumours had at least a partial regression and in three of twelve mice treated a complete tumour regression. Tumours receiving UV inactivated virus continued to grow unabated until these animals were sacrificed at day 11. Nude mice not receiving interferon and injected with live virus began to die at day 10 and only two of six remained viable by day 15. In contrast, all interferon treated, infected, nude mice were protected from VSV toxicity and remained symptom free for more than 45 days.

25           This example demonstrates that a single intratumoural injection of live VSV is efficacious against tumours. Furthermore infected, tumour bearing, nude mice can be rescued from VSV toxicity by interferon injection.

30



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**Example 19. VSV infects and kills leukemia and myeloma cells.**

The indicated cell lines were infected with VSV Indiana HR strain at a multiplicity of infection of one plaque forming unit per cell. At 24, 48 and 72 hours post infection (p.i.) samples were taken from the infected cultures and stained directly with propidium iodide following manufacturers instructions (Molecular Probes). Samples were then analysed by flow cytometry using the FACSort WinMDI Version 2.7 program. In Table 8 the percentage of cells dead for each leukemic cell type is shown for the indicated times post infection.

This example shows that VSV is able to infect and kill a diverse set of leukemia types. The K-562 cell is isolated from a chronic myelogenous leukemia (CML) patient while MOLT-4 is a T cell leukemia and SR and H929 are myelomas.

**TABLE 8**

<i>Cell Line</i>	<u>24 hr. p.i.</u>	<u>48 hr. p.i.</u>	<u>72 hr. p.i.</u>
K-562 (CML)	15.38 %	52.36 %	N/D
MOLT-4 (T cell Leukemia)	53.94 %	48.80 %	N/D
SR (Myeloma)	32.10 %	46.38 %	N/D
H929(Myeloma)	10.73 %	17.35 %	64.41 %

**Example 20: Vesicular stomatitis virus (VSV) strains including wild type Indiana and five attenuated VSV mutants demonstrate selective cytotoxicity toward human prostate carcinoma cells compared to normal human fibroblasts.**

Vesicular stomatitis virus strains including wild type Indiana and attenuated mutant strains I (TR1026), II (TR1026R), III (TP3), IV (TP6) and V (G31) were obtained from Dr. Lauren Poliquin, University of Quebec at Montreal. Each of these



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virus strains was plaque purified five times prior to use in this experiment.

Human prostate carcinoma cells (LNCAP) and normal human cells (OSF 7 forearm fibroblast) were grown in 96-well tissue culture plates to a density of approximately  $5 \times 10^4$  cells per well. Virus was added in 10-fold dilutions ranging from  $5 \times 10^5$  pfu to 5 pfu. Control wells with no virus were included on each plate. The plates were incubated for 48 hours at 37 °C in 5% CO<sub>2</sub>. Cytotoxicity was quantified using a colorimetric MTS ((3-[4,5-dimethylthiazol-2-yl]-5-[3-carboxymethoxyphenyl]-2-[4-sulfophenyl]-2H-tetrazolium, inner salt) assay (CellTiter 96 Aqueous, catalog #G1112, Promega Corporation, Madison WI 53711-5399), monitored at 490 nm, that detects mitochondrial enzyme activity. The amount of cell killing in the virus treated wells was determined by the loss in viability in the virus treated wells relative to the untreated wells. The data was plotted graphically as pfu/cell vs. percentage cell killing relative to control. The TC<sub>50</sub> for these cells was calculated as the amount of virus in pfu/cell causing a 50% reduction in the amount of viable cells. Lower TC<sub>50</sub> values reflect increased sensitivity of the cells to the lytic effects of the virus. The *in vitro* therapeutic index for each VSV strain was calculated as the ratio of TC<sub>50</sub> for the OSF7 cells compared to the TC<sub>50</sub> for the LNCAP cells.

The results are shown in Table 9. Wild type VSV-Indiana and each of the five mutants demonstrated a high degree of cytotoxicity toward the human prostate carcinoma cells as reflected in the low TC<sub>50</sub> values, all less than 0.01 pfu/cell. The normal human fibroblasts cells were one to more than 3 orders of magnitude more resistant to the cytotoxic effects of all six VSV strains. All five mutants had less toxicity on the normal OSF7 fibroblasts cells and had a higher *in vitro* therapeutic index than the wild-type Indiana VSV.

**TABLE 9. Cytotoxicity Assay Results for VSV Strains (Wild type Indiana and Mutants I through V) Against Prostate Carcinoma Cells and Normal Fibroblasts.**

	Mutant I	Mutant II	Mutant III	Mutant IV	Mutant V	WT Indiana



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LNCAP Prostate Carcinoma TC50 (pfu/cell)	0.0064	0.0048	0.0014	0.0006	0.0012	0.0017
OSF7 Normal Fibroblasts TC50 (pfu/cell)	>42	22	4.3	0.031	9.8	0.022
Therapeutic Index (TC50 OSF7/ TC50 LNCAPP)	>6562	4583	3071	52	8167	13

**Example 21: Virus Production from Tumour Cells and Normal Cells Infected with Wild Type Indiana and Various Mutant VSV Strains**

HCT 116 colon carcinoma cells and OSF 7 forearm fibroblasts were grown to confluence in 35 mm tissue culture dishes. Media was removed and virus was added in a volume of 30  $\mu$ l with a multiplicity of infection of 0.1 pfu/cell for the HCT 116 cells and 1.5 pfu/cell for the OSF 7 cells. After a 1 hour incubation period at 37°C, 5% CO<sub>2</sub>, 1 ml of tissue culture media was added to the dishes. Results are shown in Figures 10A and B. At the indicated time points, 10  $\mu$ l samples of media were removed from the dishes. The virus titre of these samples was determined by a plaque assay.

This example demonstrates the rapid replication kinetics of wild type and mutant VSV strains in HCT 116 colon carcinoma cells. All four mutant VSV strains had more rapid growth in HCT116 tumor cells than the wild type VSV. Note that in the normal OSF-7 cell cultures a ten fold higher input of virus is required to attain similar replication kinetics.



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**Example 22. Malignant cells are rapidly killed following VSV (WT Indiana) infection and are not protected by IFN- $\alpha$ .**

Monolayers of normal primary human fibroblasts (AG 1522) and several  
5 tumour cell lines were either untreated or pretreated with IFN- $\alpha$  (100 units) and then  
infected with VSV at an MOI of 0.1 pfu/ml. At 12 hours increments the infections  
were terminated by cell fixation and staining to determine the kinetics of cell killing.  
Control (CNTL) monolayers were left to grow, uninfected, over the course of the  
experiment and therefore stain more intensely. Results are shown in Figure 11.  
10 LNCAP is a human prostate carcinoma; A2780 is an human ovarian epithelial  
carcinoma, and Sk MEL3 is a human melanoma.

This example demonstrates the rapid kinetics of tumour cell killing by VSV  
Indiana even in the presence of interferon alpha. While normal cells are also killed by  
VSV, the kinetics are slower and normal cells can be completely protected by  
15 interferon alpha.

**Example 23: VSV induced cytopathic effect visible in human melanoma cells but not in primary human cells with or without IFN- $\alpha$ .**

20 Gelatin-coated coverslips with normal human cells and SK-MEL3 cells  
untreated or pretreated with IFN- $\alpha$  (100 U/ml) were infected with WT Indiana VSV at  
an MOI of 0.1 pfu/ml. Results are shown in Figure 12. The human melanoma cells  
(SK-MEL3) displayed cpe at 12 hours post-infection even in the presence of  
interferon. At 24 hours post-infection these malignant cells had died and lifted from  
25 the coverslip. Human primary cells including foreskin fibroblasts (AG1522), ovarian  
surface epithelial cells (HOSE) and prostate epithelial cells (PrEC) did not show CPE  
(cytopathic effect) until 36 hours in the absence of interferon and were completely  
protected in the presence of interferon beyond 72 hours post-infection.

This example demonstrates that VSV Indiana is able to rapidly destroy  
30 melanoma cells even in the presence of interferon alpha whereas normal fibroblasts  
and epithelial cells are slower to be killed and can be completely protected by  
interferon alpha.



**Example 24. VSV selectively kills transformed cells co-cultured with normal fibroblasts.**

5           Equal numbers of 293T cells (human embryo kidney cells transformed with adenovirus E1A and Large T antigen) and normal human foreskin fibroblasts were plated on gelatin-coated coverslips and infected (WT Indiana VSV) at an MOI of 0.1 both in the presence and absence of interferon. Cells were fixed at 12 (not shown), 24 and 36 hours post-infection. Fixed cells were stained with an anti-TAg antibody and  
10   DAPI. The red staining 293T cells were quickly killed as early as 12 hours post-infection, regardless of interferon treatment, with those few remaining cells displaying condensed or fragmented nuclei. The normal fibroblasts displayed altered nuclei by 36 hours post-infection in the absence of interferon but were protected from the virus in the presence of interferon beyond this time point.

15           This example demonstrates that in a mixed culture of normal and tumour cells, VSV Indiana preferentially replicates and kills tumour cells. Normal cells in the infected co-cultures are slower to die and can be completely rescued by interferon treatment.

20

**Example 25. Efficacy of a single intravenous dose of mutant VSV in treating human melanoma xenografts in nude mice.**

          SK-Mel3 human melanoma xenografts were established in 5-6 week old CD-1 athymic mice. On day 0, tumours were either left untreated or were treated  
25   intravenously with  $5 \times 10^9$  pfu of mutant VSV as indicated. Results are shown in Figure 13.

          This example demonstrates that mutants II and III are able to inhibit tumour growth following a single intravenous injection. Thus virus need not be administered at the tumour site to be effective in inhibiting tumour growth. Furthermore, the  
30   mutants while being attenuated for growth in normal mouse tissues, are still able to target tumour cells *in vivo*.



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**Example 26. Selective killing of AML Cells Co-cultured with normal bone marrow.**

The growth factor independent cell line OCI/AML3 was mixed 1:9 with normal bone marrow and infected for 24 hours with WT Indiana VSV. Various dilutions of cells were then plated in methylcellulose plus and minus growth factors and colony counts were performed 14 days later. Table 10 shows data for dishes receiving  $10^4$  cells. The asterisk (\*) signifies that no leukemic colonies were detected on the growth factor minus dishes even when  $10^5$  cells were plated per dish.

This example demonstrates the rapid and selective killing of leukemia cells in the presence of normal bone stem cells. Furthermore it demonstrates that bone marrow is not a dose-limiting target of VSV oncolytic therapy as it is with most other conventional cancer therapies.

**TABLE 10**

Colony Type	Multiplicity of Infection		
	0.0	1.0	5.0
Leukemic	172	0*	0*
Neutrophil	12	7	5
Mixed	6	3	4
Monocyte	10	7	5

**Example 27. VSV Sequences**

The genome of VSV contains genes that encode viral proteins N, P, M, G and L. The cDNA sequences of the open reading frames (ORF) for these proteins from wild type heat resistant VSV (HR) and three mutant VSVs were determined (based on sequencing five times each) and compared with the sequences of GenBank Accession No. NC 001560 (derived from Colorado and San Juan strains of VSV). The mutants



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are M2 (TR1026R), M3 (TP3) and M4 (TP6). The nucleic acid sequences are shown in Figures 14, 16, 18, 20 and 22. The corresponding deduced amino acid sequences are shown in Figures 15, 17, 19, 21 and 23, respectively. Differences are indicated by highlighted letters. Dotted lines represent incomplete sequencing.

5 Some of the differences between the amino acid sequences are shown in Table 11 using notation based on column heading (i.e. for column heading "Differences Between GenBank and HR" notation K155R means that the amino acid at position 155 is K in GenBank and R in HR). In those cases where HR sequence is not yet available comparisons can only be made between GenBank and a particular mutant.

10 M3\* denotes a difference between mutant 3 and HR but in this case the amino acid matches the GenBank deposit at that position (i.e. mutant 3 and the Genbank sequence agree at that position while HR is different).

This data demonstrates the many differences in sequence between the HR strain and the GenBank deposit (which is primarily derived from the San Juan strain).

15 It also demonstrates some of the differences between the mutants and the HR strain from which they were derived. These genetic differences correlate with phenotypic differences.

**TABLE 11**

Gene	Differences Between GenBank and HR	Differences Between HR and Mutants	Differences Between Genbank and Mutant #2	Differences Between GenBank and Mutant #4
N	D10A, K155R, N353S	A10D (M3*) None (M4)		
P	K50R, A76V, Q77P, E99D P110Q, S126L, S140L Y151H, M168I, E170K D237N	None (M2, M3 and M4)		
M	S32N, Y54H, N57H, T133A, I171V, I226V	M51R (M3) None (M4)		
G	H24Y, I57L, Q96H, V141A, Y172D, G132D H242R, S438T, L453F H487Y	Q26R, R242H, S431A (all M3) E254G (M4)	A331V	
L	T367A, T689S, T2026I	None (M4)		I202L, K296R



	R2075K			
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All citations are herein incorporated by reference.

5       The present invention has been described with regard to preferred embodiments. However, it will be obvious to persons skilled in the art that a number of variations and modifications can be made without departing from the scope of the invention as described herein.

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- 58 -  
CLAIMS

What is claimed is:

- 5     1.     A method of reducing the viability of a tumor cell, comprising administering to the tumor cell a virus, wherein said virus is not a common human pathogen and said tumor cell is a carcinoma, a hematopoietic tumor cell, a glioblastoma, a melanoma, a sarcoma, or a neuroendocrine tumor.
- 10    2.     The method of claim 1, wherein the tumor cell is selected from the group consisting of ovarian carcinoma, leukaemia, lung carcinoma, and colon carcinoma.
3.     The method of claim 1, wherein the tumor cell is a carcinoma.
- 15    4.     The method of claim 3, wherein the carcinoma is a lung carcinoma.
5.     The method of claim 1, wherein the tumor cell is a hematopoietic cancer cell.
6.     The method of claim 5, wherein the hematopoietic cancer cell is a leukemia, a  
20    lymphoma, or a myeloma.
7.     The method of claim 6, wherein the hematopoietic cancer cell is a leukemia.
8.     The method of claim 7, wherein the leukemia is acute myelogenous leukemia.
- 25    9.     The method of claim 7, wherein the leukemia is chronic myelogenous leukemia.



- 59 -

10. The method of claim 7, wherein the leukemia is promyelocytic leukemia.
11. The method of claim 7, wherein the leukemia is T cell leukemia.
- 5 12. The method of claim 6, wherein the hematopoietic cancer cell is a lymphoma.
13. The method of claim 6, wherein the hematopoietic cancer cell is a myeloma.
14. The method of claim 1, wherein the tumor cell is a sarcoma.
- 10 15. The method of claim 14, wherein the sarcoma is an osteosarcoma.
16. The method of claim 14, wherein the sarcoma is a fibrosarcoma.
- 15 17. The method of claim 1, wherein the tumor cell is a neuroendocrine tumor.
18. The method of claim 1, wherein the tumor cell has substantially no PKR activity.
- 20 19. The method of claim 1, wherein the tumor cell is PKR<sup>-/-</sup>; STAT1<sup>-/-</sup>; or both PKR<sup>-/-</sup> and STAT1<sup>-/-</sup>.
20. The method of claim 1, wherein the virus is a Rhabdovirus or a picornavirus.
- 25 21. The method of claim 20, wherein the virus is a Rhabdovirus.



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22. The method of claim 5, wherein the Rhabdovirus is a vesicular stomatitis virus.

23. The method of claim 22, wherein the tumor cell is leukemia.

5

24. The method of claim 23, further comprising administering interferon to the tumor cell prior to administering VSV.

25. The method of claim 22, wherein the virus is unable to inactivate PKR activity  
10 within the tumor cell.

26. The method of claim 22, wherein the virus is an attenuated strain of vesicular stomatitis virus.

15 27. The method of claim 26, wherein the virus is vesicular stomatitis virus strain M1.

28. The method of claim 26, wherein the virus is vesicular stomatitis virus strain M2.

20

29. The method of claim 26, wherein the virus is vesicular stomatitis virus strain M3.

30. The method of claim 26, wherein the virus is vesicular stomatitis virus strain  
25 M4.

31. The method of claim 26, wherein the virus is vesicular stomatitis virus strain M5.



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32. The method of claim 1, wherein the tumor cell is in a mammalian subject and the virus is administered to the tumor cell by intravenous, intranasal, intraperitoneal or intratumoral administration to the subject.

5

33. The method of claim 32, wherein the mammalian subject is a human or a non-human mammal.

34. The method of claim 32, wherein the virus is contained in cell line infected with the virus and the administration comprises administering the virus-infected cell line to the subject by a route selected from intratumorally, intravenously or intraperitoneally.

10

35. A method of reducing the viability of a tumor cell within a population of tumor cells and non-tumor cells comprising administering a vesicular stomatitis virus to the population of cells, wherein the virus is able to selectively infect and kill the tumor cell.

15

36. The method of claim 35, wherein the virus is unable to inactivate PKR activity in the tumor cell.

20

37. The method of claim 36, further comprising treating the population of cells with interferon prior to administering the virus.

38. A method for identifying a tumor susceptible to treatment with a virus, comprising:

25

- (a) dividing a sample containing cells of the tumor into a first portion and a second portion;



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- (b) treating the first portion with the virus; and
- (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion,

wherein the tumor is susceptible to treatment with the virus if the percentage of dead  
5 cells in the first portion is higher than in the second portion.

39. The method of claim 38 wherein the virus is a Rhabdovirus.

40. The method of claim 39 wherein the virus is a vesicular stomatitis virus.

10

41. The method of claim 38 wherein the percentage of dead cells is determined  
utilizing flow cytometry.

42. The method of claim 38 wherein the tumor is a solid tumor and the sample is  
15 obtained from a subject by biopsy.

43. The method of claim 42, further comprising prior to step (b) treating the tumor  
sample to disaggregate the cells.

20 44. The method of claim 38 wherein the tumor is a leukemia and the sample is  
obtained by isolating white blood cells from a blood sample to obtain the tumor cell-  
containing sample.

45. A method for identifying a tumor susceptible to treatment with a virus,  
25 comprising:

- (a) dividing a sample containing cells of the tumor into a first portion and  
a second portion;
- (b) treating the first portion with the virus and an amount of interferon



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sufficient to improve survival of interferon-responsive cells in the presence of the virus, and treating the second portion with the virus in the absence of interferon; and

- (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion,

wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion.

46. The method of claim 45 wherein the virus is a Rhabdovirus.

47. The method of claim 46 wherein the virus is a vesicular stomatitis virus.

48. The method of claim 45 wherein the percentage of dead cells is determined utilizing flow cytometry.

49. The method of claim 45 wherein the tumor is a solid tumor and the sample is obtained from a subject by biopsy.

50. The method of claim 49, further comprising prior to step (b) treating the tumor sample to disaggregate the cells.

51. The method of claim 45 wherein the tumor is a leukemia and the sample is obtained by isolating white blood cells from a blood sample to obtain the tumor cell-containing sample.

52. A method for purifying a vesicular stomatitis virus, comprising adding a sample containing the virus to an affinity matrix to produce the virus bound to the affinity matrix; washing the bound virus; and eluting the bound virus from the affinity



- 64 -

matrix.

53. The method of claim 52, wherein the affinity matrix is directed to a protein expressed on the envelope of VSV.

5

54. The method of claim 53, wherein the protein expressed on the envelope of VSV is a chimeric protein.

55. The method of claim 53, wherein the chimeric protein comprises a histidine tag, and the affinity matrix is a nickel resin.

10

56. A modified vesicular stomatitis virus expressing a non-native protein on its surface.

57. The modified virus of claim 56, wherein the non-native protein is a fusion protein comprising an affinity tag and a viral envelope protein.

15

58. The modified virus of claim 56, wherein the non-native protein is derived from a producer cell.

20

59. An isolated nucleic acid molecule having a sequence comprising:

- (a) a sequence coding for a protein comprising the amino acid sequence of Protein N of a VSV strain selected from the group consisting of HR and M3 shown in Figure 15; or
- (b) N gene cDNA sequence of a VSV strain selected from the group consisting of HR, M2 and M3 shown in Figure 14; or
- (c) RNA sequence corresponding to (b); or
- (d) a sequence complementary to (a), (b) or (c).

25



- 65 -

60. An isolated nucleic acid molecule having a sequence comprising:
- (a) a sequence coding for a protein comprising the amino acid sequence of Protein P of a VSV strain selected from the group consisting of HR, M3 and M4 shown in Figure 17; or
  - 5 (b) P gene cDNA sequence of a VSV strain selected from the group consisting of HR, M3 and M4 shown in Figure 16; or
  - (c) RNA sequence corresponding to (b); or
  - (d) a sequence complementary to (a), (b) or (c).
- 10
61. An isolated nucleic acid molecule having a sequence comprising:
- (a) a sequence coding for a protein comprising the amino acid sequence of Protein M of a VSV strain selected from the group consisting of HR, M3 and M4 shown in Figure 19; or
  - 15 (b) M gene cDNA sequence of a VSV strain selected from the group consisting of HR, M3 and M4 shown in Figure 18; or
  - (c) RNA sequence corresponding to (b); or
  - (d) a sequence complementary to (a), (b) or (c).
- 20
62. An isolated nucleic acid molecule having a sequence comprising:
- (a) a sequence coding for a protein comprising the amino acid sequence of Protein G of VSV strain M3 shown in Figure 21; or
  - (b) G gene cDNA sequence of VSV strain M3 shown in Figure 20; or
  - 25 (c) RNA sequence corresponding to (b); or
  - (d) a sequence complementary to (a), (b) or (c).
- 30
63. An isolated nucleic acid molecule having a sequence comprising:
- (a) a sequence coding for a protein comprising the amino acid sequence of Protein L of VSV strain M4 shown in Figure 23; or
  - (b) L gene cDNA sequence of VSV strain M4 shown in Figure 16; or



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- (c) RNA sequence corresponding to (b); or
- (d) a sequence complementary to (a), (b) or (c).

64. Use of a virus, said virus not being a common human pathogen, in the  
5 manufacture of a medicament for reducing the viability of a tumor cell selected from  
the group consisting of carcinomas, hematopoietic tumor cell, glioblastomas,  
melanomas, sarcomas, and neuroendocrine tumors.

65. The use of claim 64, wherein the tumor cell is selected from the group  
10 consisting of ovarian carcinoma, leukaemia, lung carcinoma, and colon carcinoma.

66. The use of claim 64, wherein the tumor cell is a carcinoma, for example a lung  
carcinoma.

15 67. The use of claim 64, wherein the tumor cell is a hematopoietic cancer cell, for  
example a leukemia such as acute myelogenous leukemia, chronic myelogenous  
leukemia, promyelocytic leukemia, or T cell leukemia; a lymphoma; or a myeloma.

68. The use of claim 64, wherein the tumor cell is a sarcoma, for example an  
20 osteosarcoma or a fibrosarcoma.

69. The use of claim 64, wherein the tumor cell is a neuroendocrine tumor.

70. The use of any one of claims 64 to 69, wherein the tumor cell has substantially  
25 no PKR activity.

71. The use of any one of claims 64 to 69, wherein the tumor cell is PKR-/-;  
STAT1-/-; or both PKR-/- and STAT1-/-.



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72. The use of any one of claims 64 to 71, wherein the virus is selected from the group consisting of Rhabdoviruses and picornaviruses.

5 73. The use of claim 72, wherein the virus is a Rhabdovirus.

74. The use of claim 73, wherein the Rhabdovirus is a vesicular stomatitis virus.

75. The use of claim 74 wherein the tumor cell is leukemia, wherein interferon is  
10 administered to the tumor cell prior to administration of VSV.

76. The use of claim 74 or 75, wherein the virus is an attenuated strain of vesicular stomatitis virus, for example M1, M2, M3, M4 or M5.

15 77. The use of any one of claims 74 to 76, wherein the tumor cell is within a population of tumor cells and non-tumor cells and the virus is administered to the population of cells.

78. The use of any one of claims 64 to 77, wherein the tumor cell is in a  
20 mammalian subject and the virus is administered to the tumor cell by intravenous, intranasal, intraperitoneal or intratumoral administration to the subject.

79. The use of any one of claims 64 to 78, wherein the mammalian subject is a human or a non-human mammal.

25

80. The use of any one of claims 64 to 79, wherein the virus is contained in cell line infected with the virus and the administration comprises administering the virus-infected cell line to the subject by a route selected from intratumorally, intravenously



or intraperitoneally.



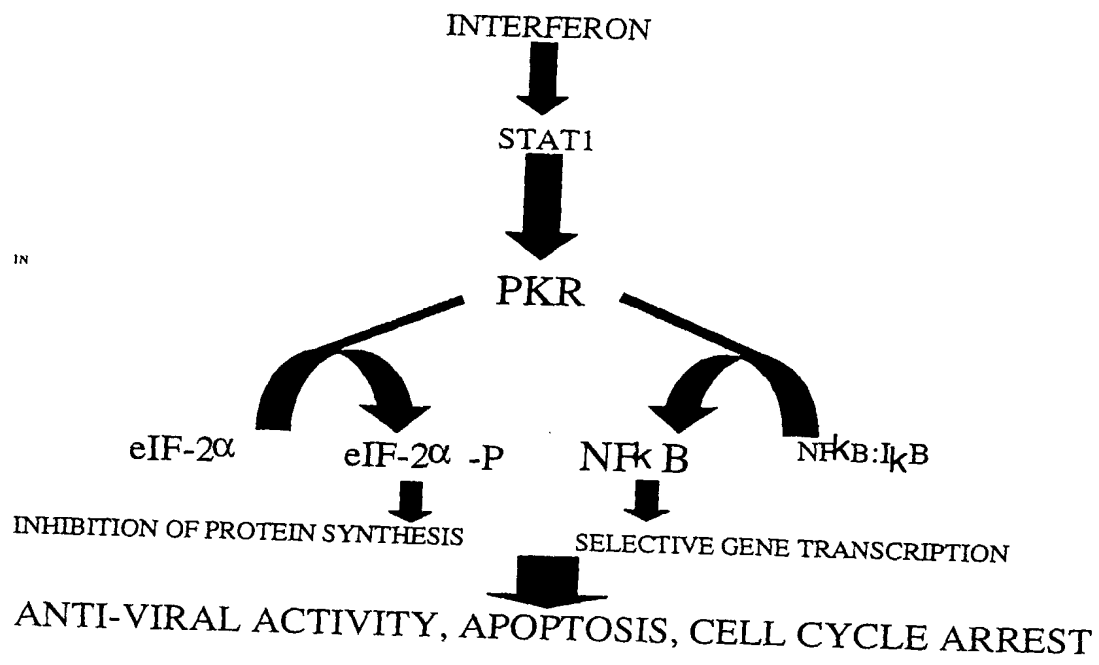


FIGURE 1



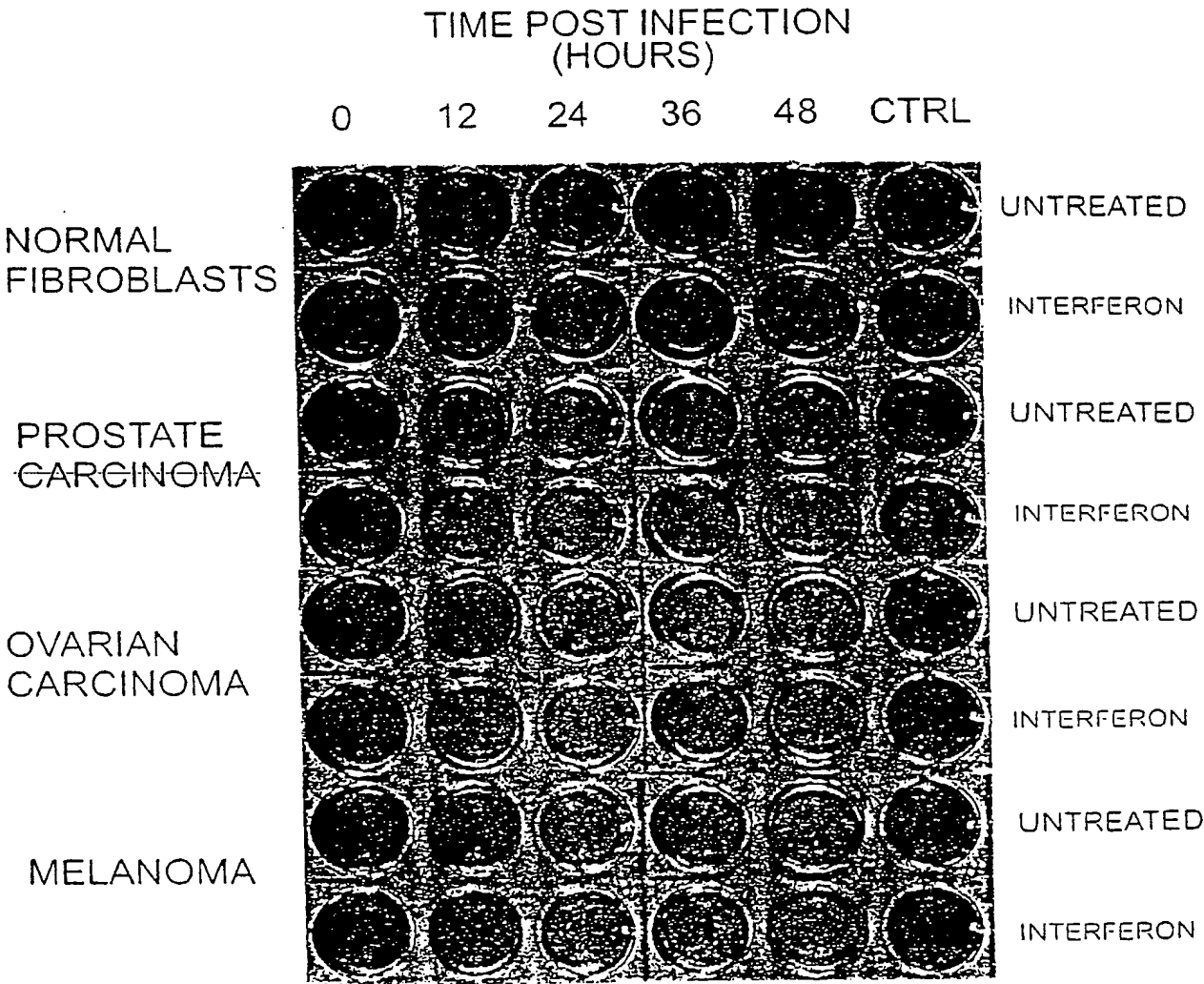


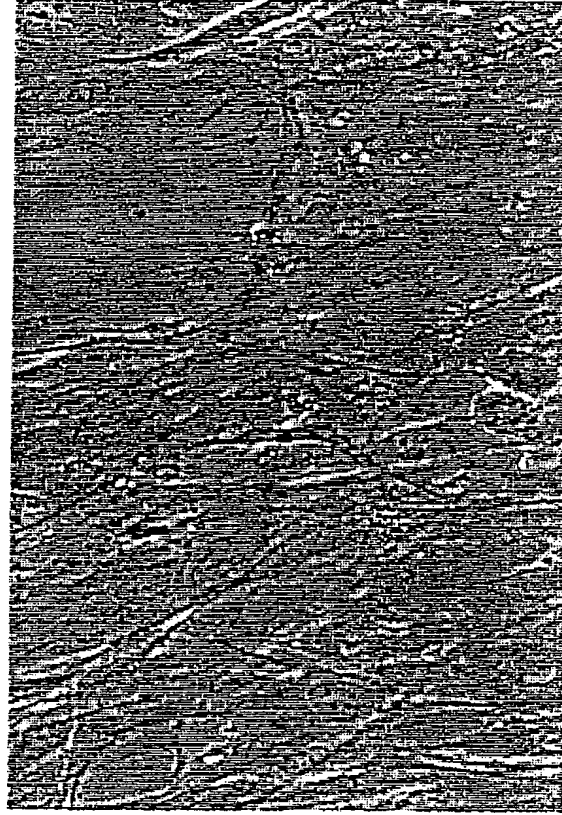
FIGURE 2



# VSV INFECTION OF NORMAL HUMAN FIBROBLASTS



MOCK INFECTED

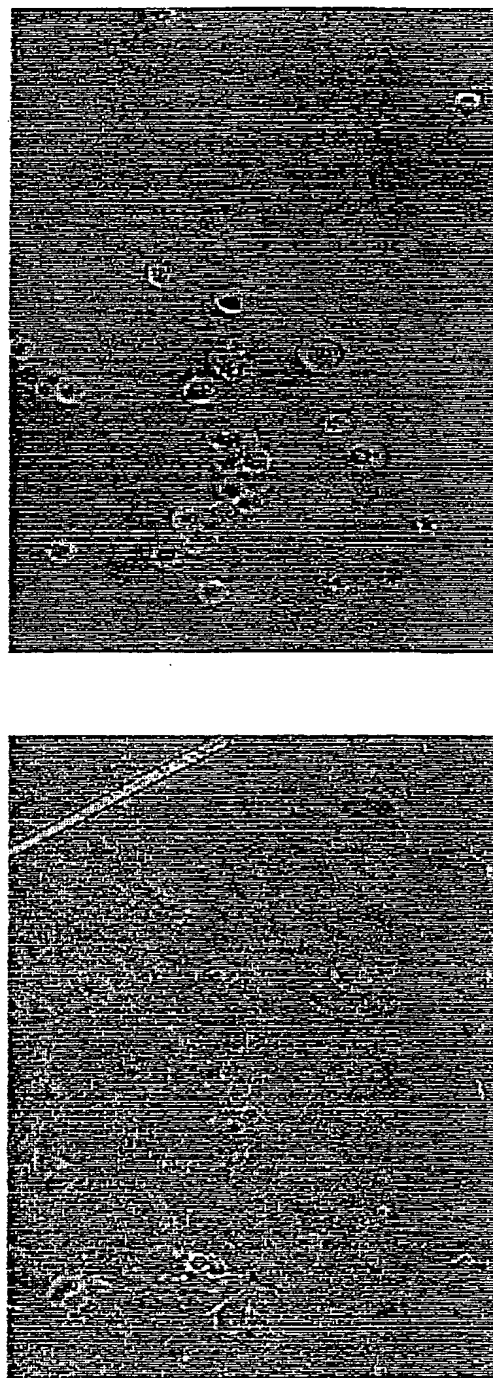


VSV MOI 1 PFU/18  
HOURS

FIGURE 3A



# VSV INFECTION OF OVCAR433



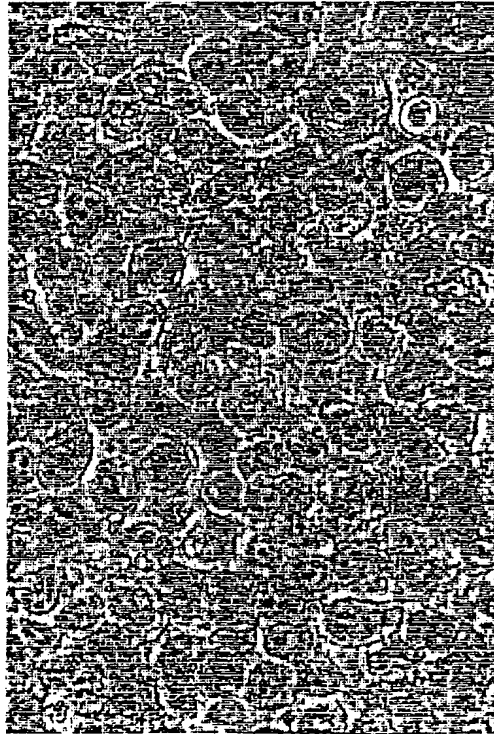
MOCK INFECTED

VSV 0.1PFU/18 HRS

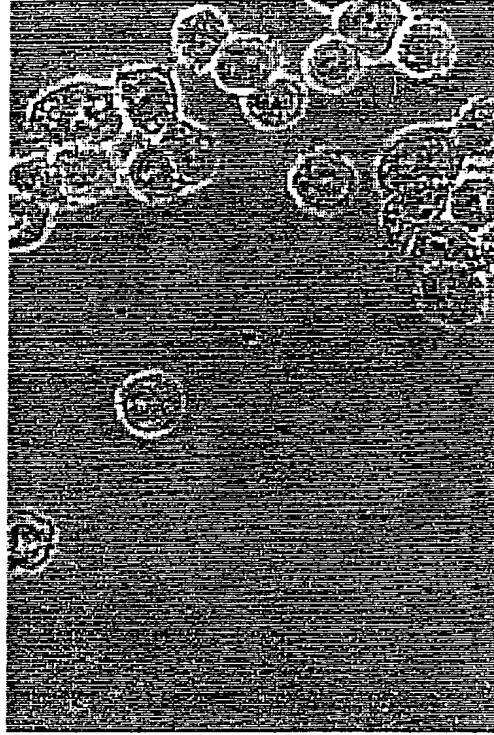
FIGURE 3B



# VSV INFECTION OF KB CELLS



MOCK INFECTED



VSV moi 1 PFU/18HRS

FIGURE 3C



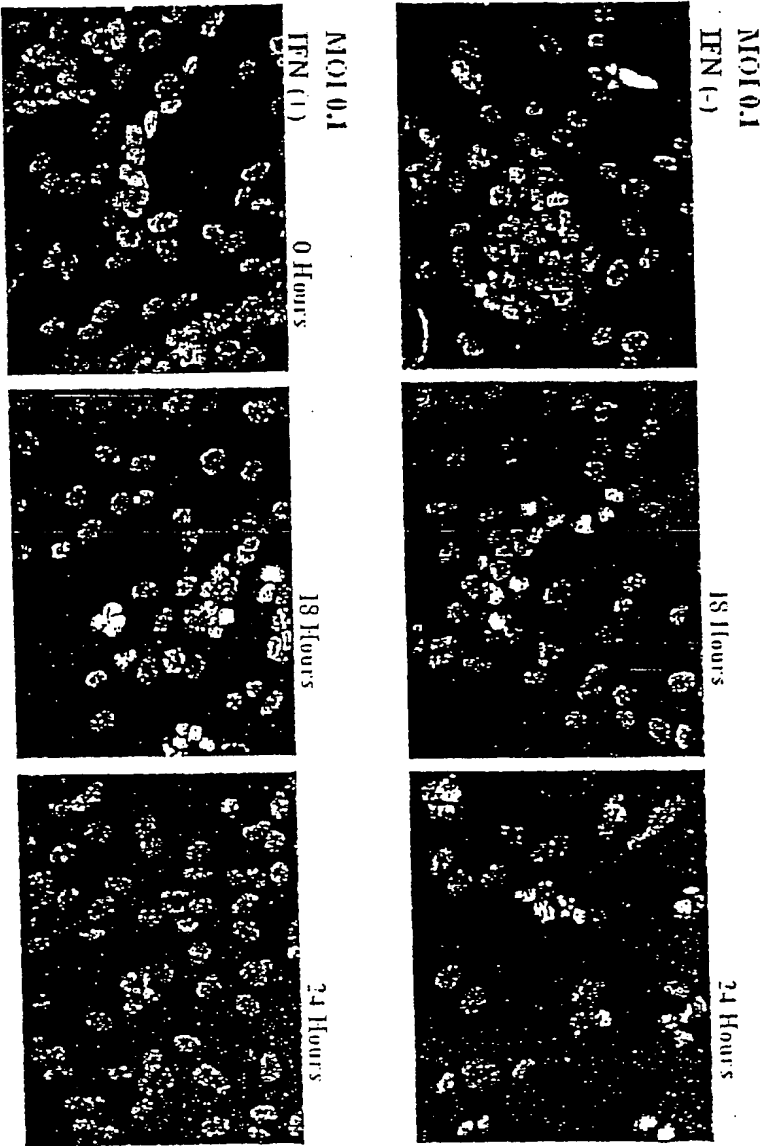


FIGURE 4



Nude Mouse Tumours

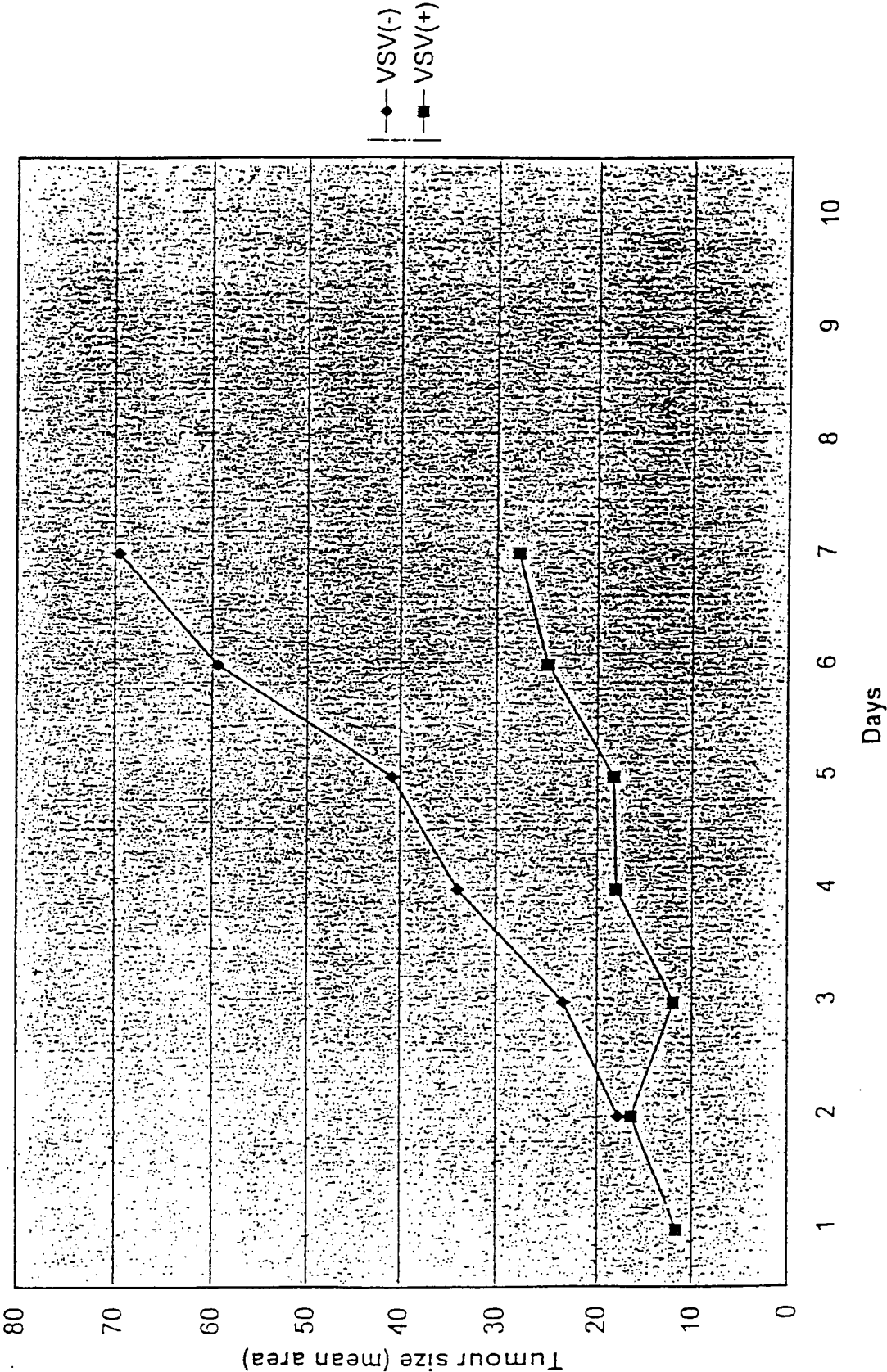


FIGURE 5





**FIGURE 6**



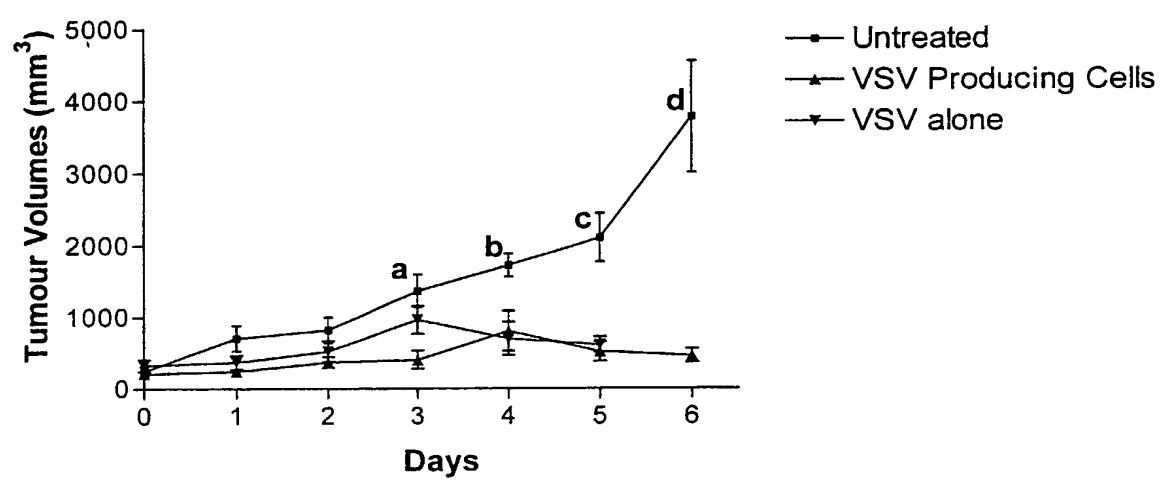
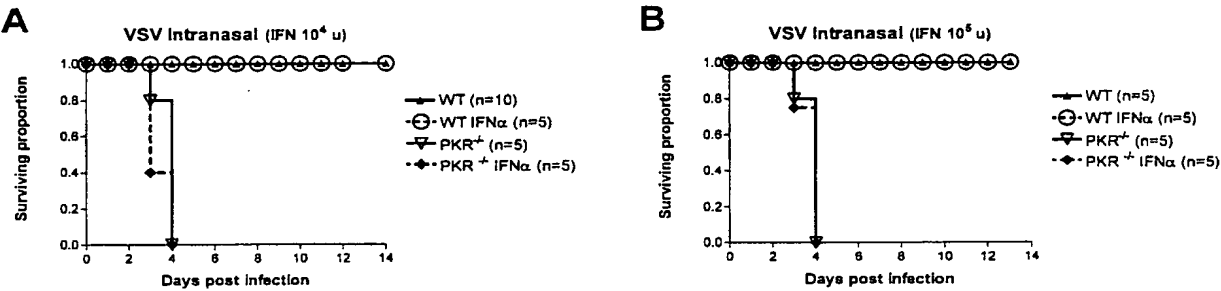


FIGURE 7





FIGURES 8A AND 8B



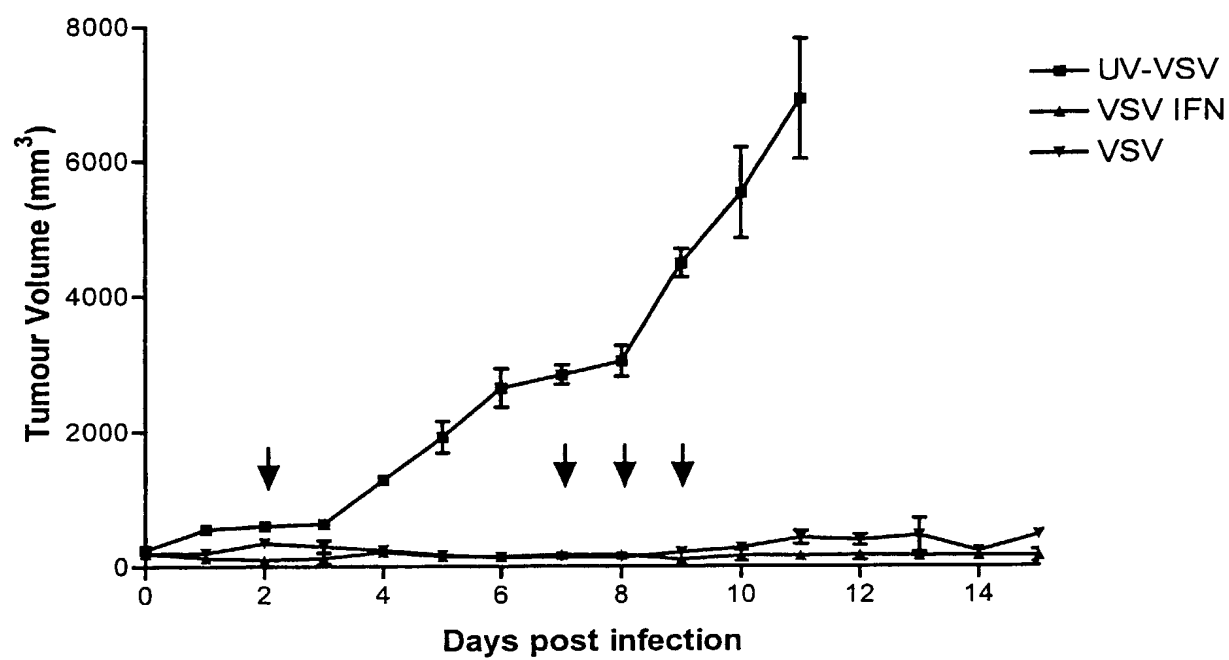
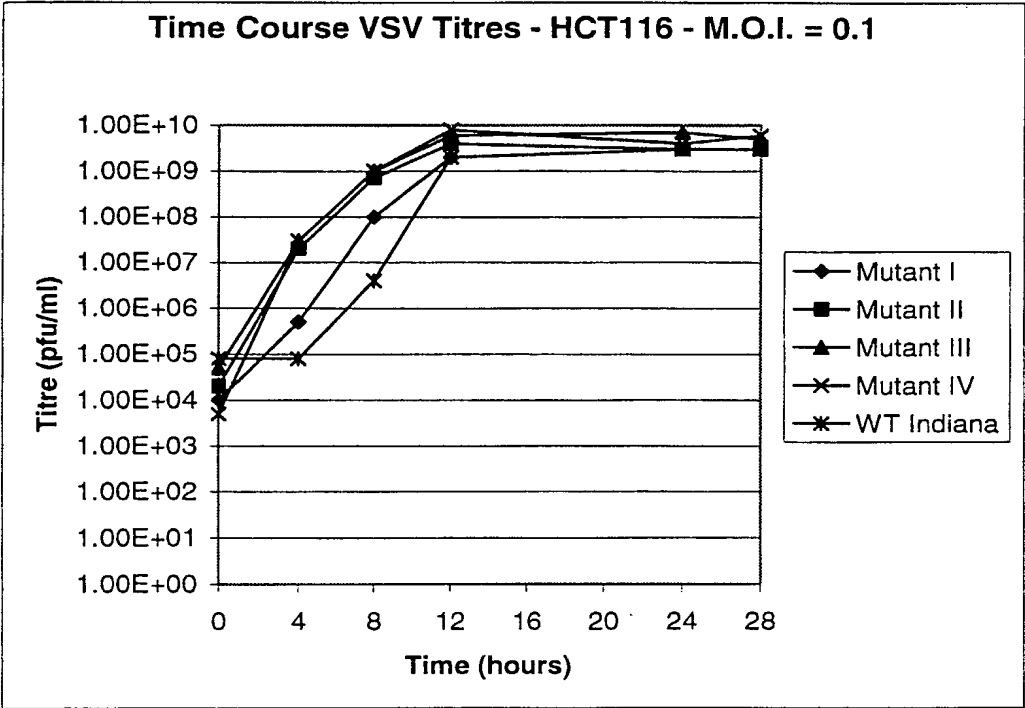


FIGURE 9





**FIGURE 10A**



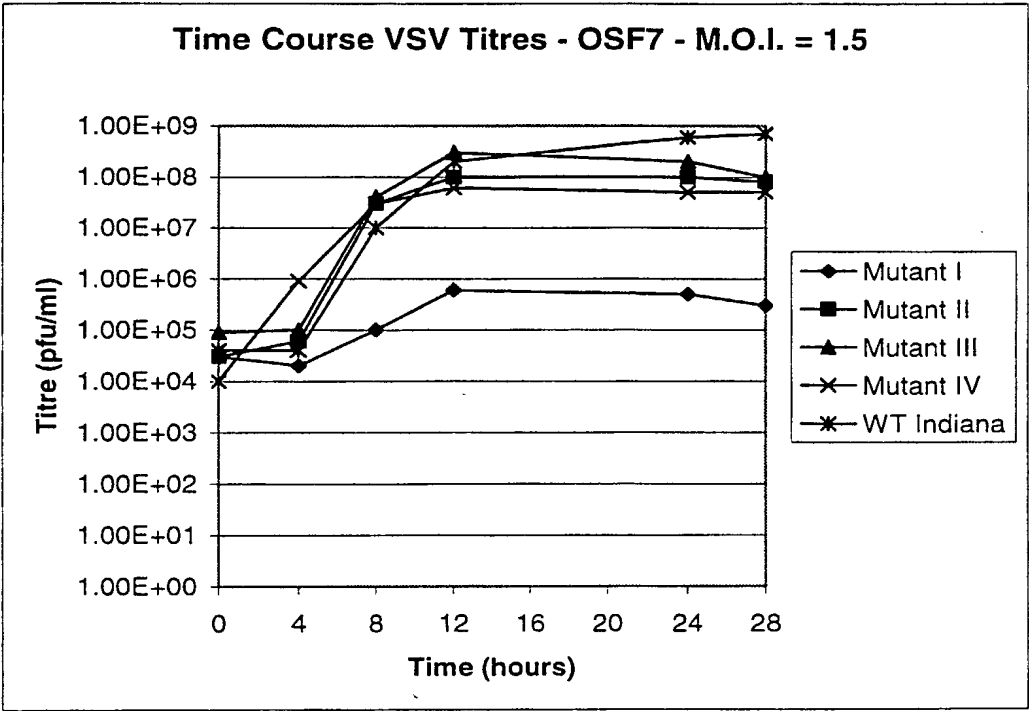


FIGURE 10B



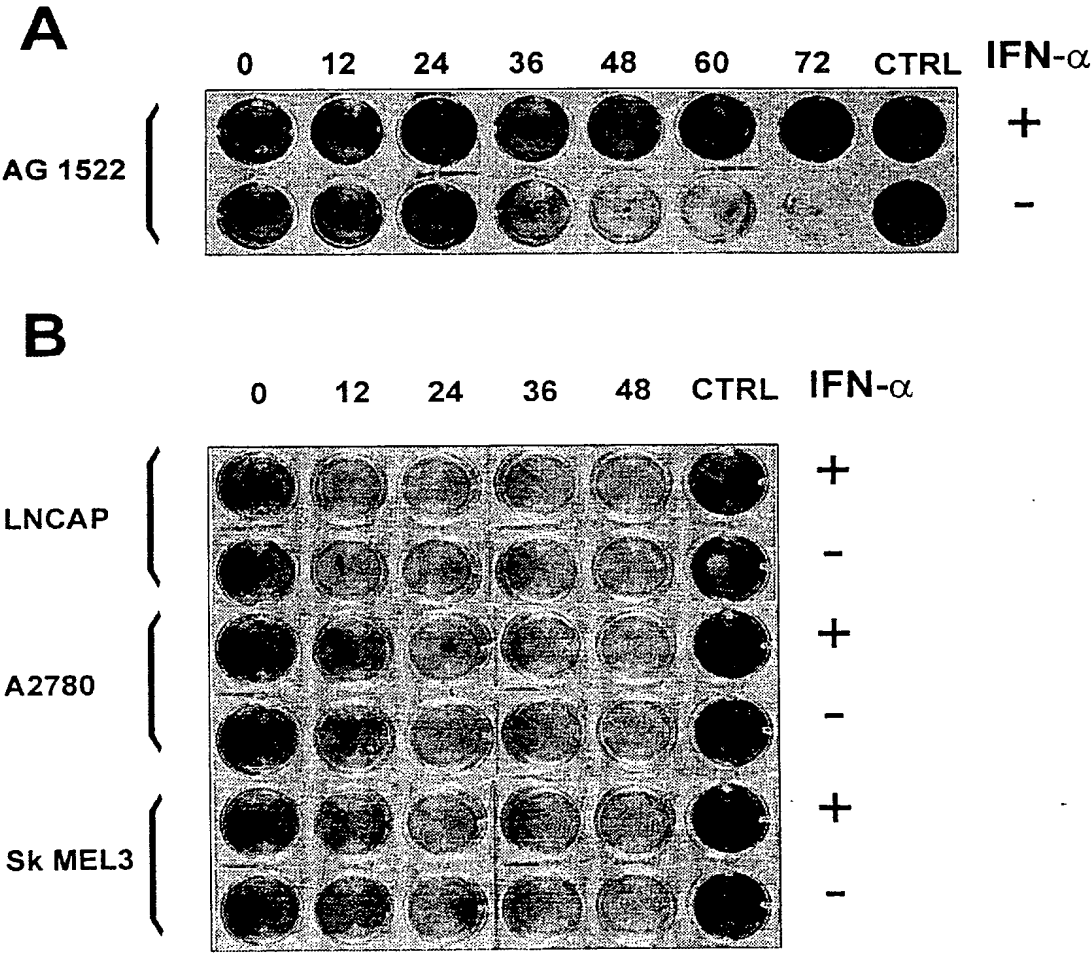


FIGURE 11



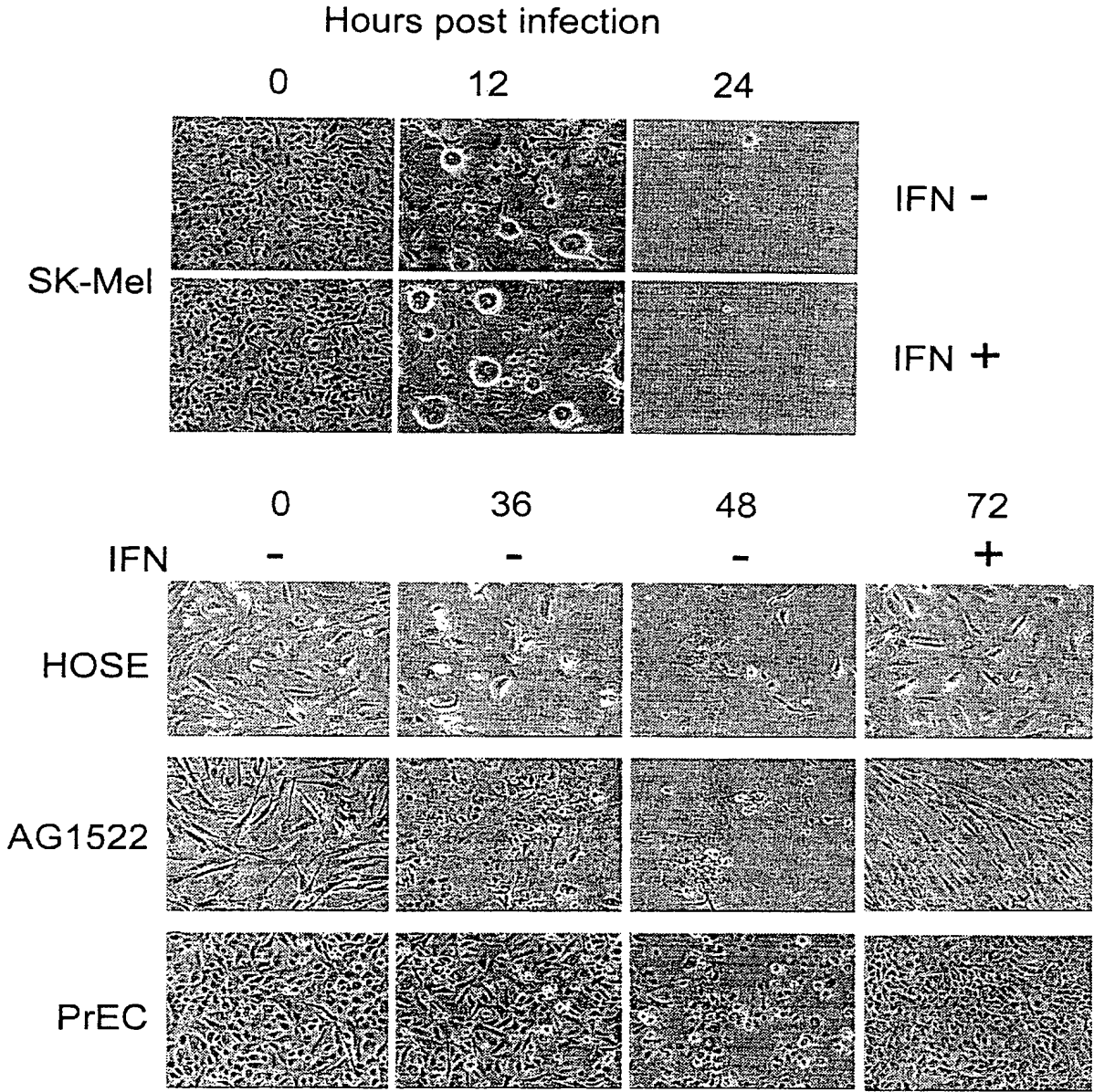
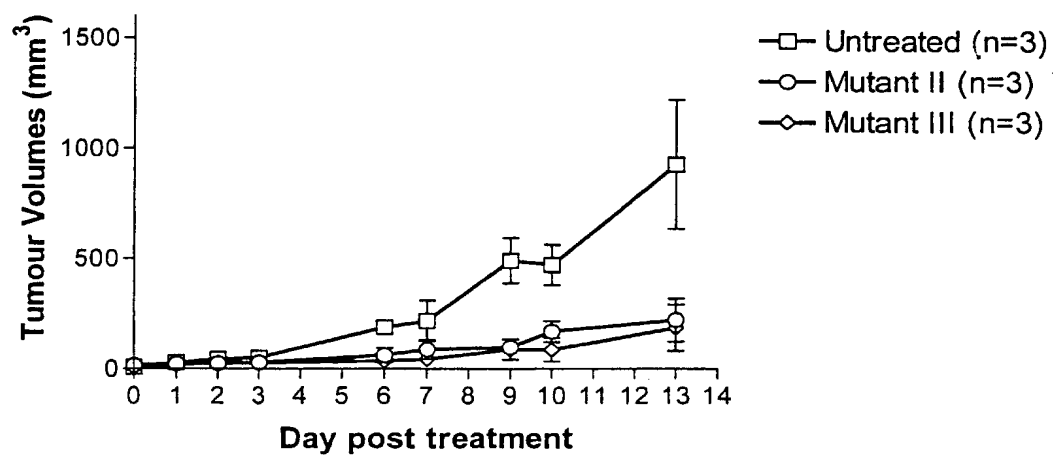


FIGURE 12



**FIGURE 13**



```

1
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M2 N nucl. ATGTCTGTTACAGTCAAGAGAATCATTGACAACACAGTCATAGTTCCAAAACCTTCCTGCA
M3 N nucl. ATGTCTGTTACAGTCAAGAGAATCATTGACAACACAGTCATAGTTCCAAAACCTTCCTGCA
M4 N nucl. ....

61
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HR N nucl. AATGAGGATCCAGTGGGAATACCCGGCAGATTACTTCAGAAAATCAAAGGAGATTCCCTCTT
M2 N nucl. AATGAGGATCCAGTGGGAATACCCGGCAGATTACTTCAGAAAATCAAAGGAGATTCCCTCTT
M3 N nucl. AATGAGGATCCAGTGGGAATACCCGGCAGATTACTTCAGAAAATCAAAGGAGATTCCCTCTT
M4 N nucl. ....

121
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M2 N nucl. TACATCAATACTACAAAAAGTTTGTTCAGATCTAAGAGGATATGTCTACCAAGGCCTCAAA
M3 N nucl. TACATCAATACTACAAAAAGTTTGTTCAGATCTAAGAGGATATGTCTACCAAGGCCTCAAA
M4 N nucl. ....

181
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M2 N nucl. TCCGGAAATGTATCAATCATACATGTCAACAGCTACTTGTATGGAGCATTGAAGGACATC
M3 N nucl. TCCGGAAATGTATCAATCATACATGTCAACAGCTACTTGTATGGAGCATTGAAGGACATC
M4 N nucl. ....TCAATCATACATGTCAACAGCTACTTGTATGGAGCATTGAAGGACATC

241
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M2 N nucl. CGGGGTAAGTTGGATAAAGATTGGTCAAGTTTCGGAATAAACATCGGGAAAGCAGGGGAT
M3 N nucl. CGGGGTAAGTTGGATAAAGATTGGTCAAGTTTCGGAATAAACATCGGGAAAGCAGGGGAT
M4 N nucl. CGGGGTAAGTTGGATAAAGATTGGTCAAGTTTCGGAATAAACATCGGGAAAGCAGGGGAT

301
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M3 N nucl. ACAATCGGAATATTTGACCTTGTATCCTTGAAAGCCCTGGACGGGTACTTCCAGATGGA
M4 N nucl. ACAATCGGAATATTTGACCTTGTATCCTTGAAAGCCCTGGACGGGTACTTCCAGATGGA

361
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M3 N nucl. GTATCGGATGCTTCCAGAACCAGCGCAGATGACAAATGGTTGCCTTTGTATCTACTTGGC
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421
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M4 N nucl. TTATACAGAGTGGGCAGAACACAAATGCCTGAATACAGAAAAAGGCTCATGGATGGGCTG

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FIGURE 14-1



		481		540
GenBank	N	nucl.	ACAAATCAATGCAAAATGATCAATGAACAGTTTGAACCTCTTGTGCCAGAAGGTCGTGAC	
	HR	N	nucl.	ACAAATCAATGCAAAATGATCAATGAACAGTTTGAACCTCTTGTGCCAGAAGGTCGTGAC
	M2	N	nucl.	ACAAATCAATGCAAAATGATCAATGAACAGTTTGAACCTCTTGTGCCAGAAGGTCGTGAC
	M3	N	nucl.	ACAAATCAATGCAAAATGATCAATGAACAGTTTGAACCTCTTGTGCCAGAAGGTCGTGAC
	M4	N	nucl.	ACAAATCAATGCAAAATGATCAATGAACAGTTTGAACCTCTTGTGCCAGAAGGTCGTGAC
		541		600
GenBank	N	nucl.	ATTTTGTGATGTGTGGGGAAATGACAGTAATTACACAAAAATTTGTCGCTGCAGTGGACATG	
	HR	N	nucl.	ATTTTGTGATGTGTGGGGAAATGACAGTAATTACACAAAAATTTGTCGCTGCAGTGGACATG
	M2	N	nucl.	ATTTTGTGATGTGTGGGGAAATGACAGTAATTACACAAAAATTTGTCGCTGCAGTGGACATG
	M3	N	nucl.	ATTTTGTGATGTGTGGGGAAATGACAGTAATTACACAAAAATTTGTCGCTGCAGTGGACATG
	M4	N	nucl.	ATTTTGTGATGTGTGGGGAAATGACAGTAATTACACAAAAATTTGTCGCTGCAGTGGACATG
		601		660
GenBank	N	nucl.	TTCTTCCACATGTTCAAAAAACATGAATGTGCCTCGTTCAGATACGGAACATTGTTTCC	
	HR	N	nucl.	TTCTTCCACATGTTCAAAAAACATGAATGTGCCTCGTTCAGATACGGAACATTGTTTCC
	M2	N	nucl.	TTCTTCCACATGTTCAAAAAACATGAATGTGCCTCGTTCAGATACGGAACATTGTTTCC
	M3	N	nucl.	TTCTTCCACATGTTCAAAAAACATGAATGTGCCTCGTTCAGATACGGAACATTGTTTCC
	M4	N	nucl.	TTCTTCCACATGTTCAAAAAACATGAATGTGCCTCGTTCAGATACGGAACATTGTTTCC
		661		720
GenBank	N	nucl.	AGATTCAAAGATTGTGCTGCATTGGCAACATTTGGACACCTCTGCAAAATAACCGGAATG	
	HR	N	nucl.	AGATTCAAAGATTGTGCTGCATTGGCAACATTTGGACACCTCTGCAAAATAACCGGAATG
	M2	N	nucl.	AGATTCAAAGATTGTGCTGCATTGGCAACATTTGGACACCTCTGCAAAATAACCGGAATG
	M3	N	nucl.	AGATTCAAAGATTGTGCTGCATTGGCAACATTTGGACACCTCTGCAAAATAACCGGAATG
	M4	N	nucl.	AGATTCAAAGATTGTGCTGCATTGGCAACATTTGGACACCTCTGCAAAATAACCGGAATG
		721		780
GenBank	N	nucl.	TCTACAGAAGATGTAACGACCTGGATCTTGAACCGAGAAGTTGCAGATGAGATGGTCCAA	
	HR	N	nucl.	TCTACAGAAGATGTAACGACCTGGATCTTGAACCGAGAAGTTGCAGATGAGATGGTCCAA
	M2	N	nucl.	TCTACAGAAGATGTAACGACCTGGATCTTGAACCGAGAAGTTGCAGATGAGATGGTCCAA
	M3	N	nucl.	TCTACAGAAGATGTAACGACCTGGATCTTGAACCGAGAAGTTGCAGATGAGATGGTCCAA
	M4	N	nucl.	TCTACAGAAGATGTAACGACCTGGATCTTGAACCGAGAAGTTGCAGATGAGATGGTCCAA
		781		840
GenBank	N	nucl.	ATGATGCTTCCAGGCCAAGAAATTGACAAGGCCGATTTCATACATGCCTTATTTGATCGAC	
	HR	N	nucl.	ATGATGCTTCCAGGCCAAGAAATTGACAAGGCCGATTTCATACATGCCTTATTTGATCGAC
	M2	N	nucl.	ATGATGCTTCCAGGCCAAGAAATTGACAAGGCCGATTTCATACATGCCTTATTTGATCGAC
	M3	N	nucl.	ATGATGCTTCCAGGCCAAGAAATTGACAAGGCCGATTTCATACATGCCTTATTTGATCGAC
	M4	N	nucl.	ATGATGCTTCCAGGCCAAGAAATTGACAAGGCCGATTTCATACATGCCTTATTTGATCGAC
		841		900
GenBank	N	nucl.	TTTGGATTGTCTTCTAAGTCTCCATATTCTTCCGTCAAAAACCCTGCCTTCCACTTCTGG	
	HR	N	nucl.	TTTGGATTGTCTTCTAAGTCTCCATATTCTTCCGTCAAAAACCCTGCCTTCCACTTCTGG
	M2	N	nucl.	TTTGGATTGTCTTCTAAGTCTCCATATTCTTCCGTCAAAAACCCTGCCTTCCACTTCTGG
	M3	N	nucl.	TTTGGATTGTCTTCTAAGTCTCCATATTCTTCCGTCAAAAACCCTGCCTTCCACTTCTGG
	M4	N	nucl.	TTTGGATTGTCTTCTAAGTCTCCATATTCTTCCGTCAAAAACCCTGCCTTCCACTTCTGG

FIGURE 14-2



```

GenBank N nucl. 901 960
HR N nucl. GGGCAATTGACAGCTCTTCTGCTCAGATCCACCAGAGCAAGGAATGCCCCGACAGCCTGAT
M2 N nucl. GGGCAATTGACAGCTCTTCTGCTCAGATCCACCAGAGCAAGGAATGCCCCGACAGCCTGAT
M3 N nucl. GGGCAATTGACAGCTCTTCTGCTCAGATCCACCAGAGCAAGGAATGCCCCGACAGCCTGAT
M4 N nucl. GGGCAATTGAC.....T

GenBank N nucl. 961 1020
HR N nucl. GACATTGAGTATACATCTCTTACTACAGCAGGTTTGTGTACGCTTATGCAGTAGGATCC
M2 N nucl. GACATTGAGTATACATCTCTTACTACAGCAGGTTTGTGTACGCTTATGCAGTAGGATCC
M3 N nucl. GACATTGAGTATACATCTCTTACTACAGCAGGTTTGTGTACGCTTATGCAGTAGGATCC
M4 N nucl. GACATTGAGTATACATCTCTTACTACAGCAGGTTTGTGTACGCTTATGCAGTAGGATCC

GenBank N nucl. 1021 1080
HR N nucl. TCTGCTGACTTGGCACAACAGTTTTGTGTTGGAGATACAAATACACTCCAGATGATAGT
M2 N nucl. TCTGCTGACTTGGCACAACAGTTTTGTGTTGGAGATAGCAAATACACTCCAGATGATAGT
M3 N nucl. TCTGCTGACTTGGCACAACAGTTTTGTGTTGGAGATAGCAAATACACTCCAGATGATAGT
M4 N nucl. TCTGCTGACTTGGCACAACAGTTTTGTGTTGGAGATAGCAAATACACTCCAGATGATAGT

GenBank N nucl. 1081 1140
HR N nucl. ACCGGAGGATTGACGACTAATGCACCGCCACAAGGCAGAGATGTGGTCGAATGGCTCGGA
M2 N nucl. ACCGGAGGATTGACGACTAATGCACCGCCACAAGGCAGAGATGTGGTCGAATGGCTCGGA
M3 N nucl. ACCGGAGGATTGACGACTAATGCACCGCCACAAGGCAGAGATGTGGTCGAATGGCTCGGA
M4 N nucl. ACCGGAGGATTGACGACTAATGCACCGCCACAAGGCAGAGATGTGGTCGAATGGCTCGGA

GenBank N nucl. 1141 1200
HR N nucl. TGGTTTGAAGATCAAAACAGAAAACCGACTCCTGATATGATGCAGTATGCGAAAAGAGCA
M2 N nucl. TGGTTTGAAGATCAAAACAGAAAACCGACTCCTGATATGATGCAGTATGCGAAAACGAGCA
M3 N nucl. TGGTTTGAAGATCAAAACAGAAAACCGACTCCTGATATGATGCAGTATGCGAAAACGAGCA
M4 N nucl. TGGTTTGAAGATCAAAACAGAAAACCGACTCCTGATATGATGCAGTATGCGAAAACGAGCA

GenBank N nucl. 1201 1260
HR N nucl. GTCATGTCACTGCAAGGCCTAAGAGAGAAGACAATTGGCAAGTATGCTAAGTCAGAATTT
M2 N nucl. GTCATGTCACTGCAAGGCCTAAGAGAGAAGACAATTGGCAAGTATGCTAAGTCAGAATTT
M3 N nucl. GTCATGTCACTGCAAGGCCTAAGAGAGAAGACAATTGGCAAGTATGCTAAGTCAGAATTT
M4 N nucl. GTCATGTCACTGCAAGGCCTAAGAGAGAAGACAATTGGCAAGTATGCTAAGTCAGAATTT

GenBank N nucl. 1261 1269
HR N nucl. GACAAATGA
M2 N nucl. GACAAATGA
M3 N nucl. GACAAATGA
M4 N nucl. GACAAATGA

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FIGURE 14-3



		1	60
GenBank	N a.a.	MSVTVKRIIDNTVIVPKLPANEDPVEYPADYFRKSKEIPLYINTTKSLSDLRGYVYQGLK	
	HR N a.a.	MSVTVKRIIDNTVIVPKLPANEDPVEYPADYFRKSKEIPLYINTTKSLSDLRGYVYQGLK	
	M3 N a.a.	MSVTVKRIIDNTVIVPKLPANEDPVEYPADYFRKSKEIPLYINTTKSLSDLRGYVYQGLK	
	M4 N a.a.	.....	
		61	120
GenBank	N a.a.	SGNVSIHVNNSYLYGALKDIRGKLDKDWSFGINIGKAGDTIGIFDLVSLKALDGVLPDG	
	HR N a.a.	SGNVSIHVNNSYLYGALKDIRGKLDKDWSFGINIGKAGDTIGIFDLVSLKALDGVLPDG	
	M3 N a.a.	SGNVSIHVNNSYLYGALKDIRGKLDKDWSFGINIGKAGDTIGIFDLVSLKALDGVLPDG	
	M4 N a.a.	....SIHVNNSYLYGALKDIRGKLDKDWSFGINIGKAGDTIGIFDLVSLKALDGVLPDG	
		121	180
GenBank	N a.a.	VSDASRTSADDKWLPLYLLGLYRVGRTQMPEYRKRLMDGLTNQCKMINEQFEPLVPEGRD	
	HR N a.a.	VSDASRTSADDKWLPLYLLGLYRVGRTQMPEYRKRLMDGLTNQCKMINEQFEPLVPEGRD	
	M3 N a.a.	VSDASRTSADDKWLPLYLLGLYRVGRTQMPEYRKRLMDGLTNQCKMINEQFEPLVPEGRD	
	M4 N a.a.	VSDASRTSADDKWLPLYLLGLYRVGRTQMPEYRKRLMDGLTNQCKMINEQFEPLVPEGRD	
		181	240
GenBank	N a.a.	IFDVWGNDNSNYTKIVAADMFFHMFKKHECASFRYGTIVSRFKDCAALATFGHLCKITGM	
	HR N a.a.	IFDVWGNDNSNYTKIVAADMFFHMFKKHECASFRYGTIVSRFKDCAALATFGHLCKITGM	
	M3 N a.a.	IFDVWGNDNSNYTKIVAADMFFHMFKKHECASFRYGTIVSRFKDCAALATFGHLCKITGM	
	M4 N a.a.	IFDVWGNDNSNYTKIVAADMFFHMFKKHECASFRYGTIVSRFKDCAALATFGHLCKITGM	
		241	300
GenBank	N a.a.	STEDVTTWILNREVADEMVMMLPGQEIDKADSYMPYLIDFGLSSKSPYSSVKNPAFHFW	
	HR N a.a.	STEDVTTWILNREVADEMVMMLPGQEIDKADSYMPYLIDFGLSSKSPYSSVKNPAFHFW	
	M3 N a.a.	STEDVTTWILNREVADEMVMMLPGQEIDKADSYMPYLIDFGLSSKSPYSSVKNPAFHFW	
	M4 N a.a.	STEDVTTWILNREVADEMVMMLPGQEIDKADSYMPYLIDFGLSSKSPYSSVKNPAFHFW	
		301	360
GenBank	N a.a.	GQLTALLLRSTRARNARQPDDIEYTSLTAGLLYAYAVGSSADLAQQFCVGDNKYTPDDS	
	HR N a.a.	GQLTALLLRSTRARNARQPDDIEYTSLTAGLLYAYAVGSSADLAQQFCVGDNSKYTPDDS	
	M3 N a.a.	GQLTALLLRSTRARNARQPDDIEYTSLTAGLLYAYAVGSSADLAQQFCVGDNSKYTPDDS	
	M4 N a.a.	GQLT.....DIEYTSXTTAGLLYAYAVGSSADLAXQFCVGDNSKYTPDDS	
		361	420
GenBank	N a.a.	TGGLTTNAPPQGRDVVEWLGWFEDQNRKPTPDMMQYAKRAVMSLQGLREKTIGKYAKSEF	
	HR N a.a.	TGGLTTNAPPQGRDVVEWLGWFEDQNRKPTPDMMQYAKRAVMSLQGLREKTIGKYAKSEF	
	M3 N a.a.	TGGLTTNAPPQGRDVVEWLGWFEDQNRKPTPDMMQYAKRAVMSLQGLREKTIGKYAKSEF	
	M4 N a.a.	TGGLTTNAPPQGRDVVEWLGWFEDQNRKPTPDMMQYAKRAVMSLQGLREKTIGKYAKSEF	
		421	423
GenBank	N a.a.	DK.	
	HR N a.a.	DK.	
	M3 N a.a.	DK.	
	M4 N a.a.	DK.	

FIGURE 15



		1	60
GenBank	P nucl.	ATGGATAATCTCACAAAAGTTCGTGAGTATCTCAAGTCCTATTCTCGTCT	GATCAGGCG
HR	P nucl.	ATGGATAATCTCACAAAAGTTCGTGAGTATCTCAAGTCCTATTCTCGTCTAGATCAGGCG	
M2	P nucl.	ATGGATAATCTCACAAAAGTTCGTGAGTATCTCAAGTCCTATTCTCGTCTAGATCAGGCG	
M3	P nucl.	ATGGATAATCTCACAAAAGTTCGTGAGTATCTCAAGTCCTATTCTCGTCTAGATCAGGCG	
M4	P nucl.	ATGGATAATCTCACAAAAGTTCGTGAGTATCTCAAGTCCTATTCTCGTCTAGATCAGGCG	
		61	120
GenBank	P nucl.	GTAGGAGAGATAGATGAGATCGAAGCACAACGAGCTGAAAAGTCCAATTATGAGTTGTTT	
HR	P nucl.	GTAGGAGAGATAGATGAGATCGAAGCACAACGAGCTGAAAAGTCCAATTATGAGTTGTTT	
M2	P nucl.	GTAGGAGAGATAGATGAGATCGAAGCACAACGAGCTGAAAAGTCCAATTATGAGTTGTTT	
M3	P nucl.	GTAGGAGAGATAGATGAGATCGAAGCACAACGAGCTGAAAAGTCCAATTATGAGTTGTTT	
M4	P nucl.	GTAGGAGAGATAGATGAGATCGAAGCACAACGAGCTGAAAAGTCCAATTATGAGTTGTTT	
		121	180
GenBank	P nucl.	CAAGAGGATGGAGTGGAAGAGCATACTAGCCCTCTTATTTTCAGGCAGCAGATGATTCT	
HR	P nucl.	CAAGAGGACGGAGTGGAAGAGCATACTAGGCCCTCTTATTTTCAGGCAGCAGATGATTCT	
M2	P nucl.	CAAGAGGACGGAGTGGAAGAGCATACTAGGCCCTCTTATTTTCAGGCAGCAGATGATTCT	
M3	P nucl.	CAAGAGGACGGAGTGGAAGAGCATACTAGGCCCTCTTATTTTCAGGCAGCAGATGATTCT	
M4	P nucl.	CAAGAGGACGGAGTGGAAGAGCATACTAGGCCCTCTTATTTTCAGGCAGCAGATGATTCT	
		181	240
GenBank	P nucl.	GACACAGAATCTGAACCAGAAATTGAAGACAATCAAGGTTTGTATGCACAGGATCCAGAA	
HR	P nucl.	GACACAGAATCTGAACCAGAAATTGAAGACAATCAAGGCTTGTATGTACCAGATCCGGAA	
M2	P nucl.	GACACAGAATCTGAACCAGAAATTGAAGACAATCAAGGCTTGTATGTACCAGATCCGGAA	
M3	P nucl.	GACACAGAATCTGAACCAGAAATTGAAGACAATCAAGGCTTGTATGTACCAGATCCGGAA	
M4	P nucl.	GACACAGAATCTGAACCAGAAATTGAAGACAATCAAGGCTTGTATGTACCAGATCCGGAA	
		241	300
GenBank	P nucl.	GCTGAGCAAGTTGAAGGCTTTTATACAGGGGCCTTTAGATGACTATGCGGATGAGGACGTG	
HR	P nucl.	GCTGAGCAAGTTGAAGGCTTTTATACAGGGGCCTTTAGATGACTATGCGGATGAGGACGTG	
M2	P nucl.	GCTGAGCAAGTTGAAGGCTTTTATACAGGGGCCTTTAGATGACTATGCGGATGAGGACGTG	
M3	P nucl.	GCTGAGCAAGTTGAAGGCTTTTATACAGGGGCCTTTAGATGACTATGCGGATGAGGACGTG	
M4	P nucl.	GCTGAGCAAGTTGAAGGCTTTTATACAGGGGCCTTTAGATGACTATGCGGATGAGGACGTG	
		301	360
GenBank	P nucl.	GATGTTGTATTCACTTCGGACTGGAAACCACTGAGCTTGAATCTGACGAGCATGGAAAG	
HR	P nucl.	GATGTTGTATTCACTTCGGACTGGAAACAGCCTGAGCTTGAATCCGACGAGCATGGAAAG	
M2	P nucl.	GATGTTGTATTCACTTCGGACTGGAAACAGCCTGAGCTTGAATCCGACGAGCATGGAAAG	
M3	P nucl.	GATGTTGTATTCACTTCGGACTGGAAACAGCCTGAGCTTGAATCCGACGAGCATGGAAAG	
M4	P nucl.	GATGTTGTATTCACTTCGGACTGGAAACAGCCTGAGCTTGAATCCGACGAGCATGGAAAG	
		361	420
GenBank	P nucl.	ACCTTACGGTTGACATTGCCAGAGGGTTTAAGTGGAGAGCAGAAATCCCAGTGGCTTTG	
HR	P nucl.	ACCTTACGGTTGACATTGCCAGAGGGTTTAAGTGGAGAGCAGAAATCCCAGTGGCTTTTG	
M2	P nucl.	ACCTTACGGTTGACATTGCCAGAGGGTTTAAGTGGAGAGCAGAAATCCCAGTGGCTTTTG	
M3	P nucl.	ACCTTACGGTTGACATTGCCAGAGGGTTTAAGTGGAGAGCAGAAATCCCAGTGGCTTTTG	
M4	P nucl.	ACCTTACGGTTGACATTGCCAGAGGGTTTAAGTGGAGAGCAGAAATCCCAGTGGCTTTTG	

FIGURE 16-1



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421
GenBank P nucl. ACGATTAAAGCAGTCGTCCAAAGTGCCAAACTACTGGAATCTGGCAGAGTGCACATTTGAA 480
HR P nucl. ACGATTAAAGCAGTCGTTCAAAGTGCCAAACACTGGAATCTGGCAGAGTGCACATTTGAA
M2 P nucl. ACGATTAAAGCAGTCGTTCAAAGTGCCAAACACTGGAATCTGGCAGAGTGCACATTTGAA
M3 P nucl. ACGATTAAAGCAGTCGTTCAAAGTGCCAAACACTGGAATCTGGCAGAGTGCACATTTGAA
M4 P nucl. ACGATTAAAGCAGTCGTTCAAAGTGCCAAACACTGGAATCTGGCAGAGTGCACATTTGAA

481
GenBank P nucl. GCATCGGGAGAAGGGGTCATTTATCAAGCGAGCGCCAGATAACTCCGGATGTATATAAGGTC 540
HR P nucl. GCATCGGGAGAAGGGGTCATCATAAAAAAGCGCCAGATAACTCCGGATGTATATAAGGTC
M2 P nucl. GCATCGGGAGAAGGGGTCATCATAAAAAAGCGCCAGATAACTCCGGATGTATATAAGGTC
M3 P nucl. GCATCGGGAGAAGGGGTCATCATAAAAAAGCGCCAGATAACTCCGGATGTATATAAGGTC
M4 P nucl. GCATCGGGAGAAGGGGTCATCATAAAAAAGCGCCAGATAACTCCGGATGTATATAAGGTC

541
GenBank P nucl. ACTCCAGTGATGAACACACATCCGTCCCAATCAGAAGCGTATCAGATGTTTGGTCTCTC 600
HR P nucl. ACTCCAGTGATGAACACACATCCGTCCCAATCAGAAGCCGTATCAGATGTTTGGTCTCTC
M2 P nucl. ACTCCAGTGATGAACACACATCCGTCCCAA.....
M3 P nucl. ACTCCAGTGATGAACACACATCCGTCCCAATCGGAAGCCGTATCAGATGTTTGGTCTCTC
M4 P nucl. ACTCCAGTGATGAACACACATCCGTCCCAATCAGAAGCCGTATCAGATGTTTGGTCTCTC

601
GenBank P nucl. TCAAAGACATCCATGACTTTCCAACCCAAGAAAGCAAGTCTTCAGCCTCTCACCATATCC 660
HR P nucl. TCAAAGACATCCATGACTTTCCAACCCAAGAAAGCAAGTCTTCAGCCTCTCACCATATCC
M2 P nucl. ....
M3 P nucl. TCAAAGACATCCATGACTTTCCAACCCAAGAAAGCAAGTCTTCAGCCTCTCACCATATCC
M4 P nucl. TCAAAGACATCCATGACTTTCCAACCCAAGAAAGCAAGTCTTCAGCCTCTCACCATATCC

661
GenBank P nucl. TTGGATGAATTGTTCTCATCTAGAGGAGATTTCATCTCTGTTCGGAGGTACGGACGAATG 720
HR P nucl. TTGGATGAATTGTTCTCATCTAGAGGAGAATTCATCTCTGTTCGGAGGTAAACGGACGAATG
M2 P nucl. ....
M3 P nucl. TTGGATGAATTGTTCTCATCTAGAGGAGAATTCATCTCTGTTCGGAGGTAAACGGACGAATG
M4 P nucl. TTGGATGAATTGTTCTCATCTAGAGGAGAATTCATCTCTGTTCGGAGGTAAACGGACGAATG

721
GenBank P nucl. TCTCATAAAGAGGCCATCCTGCTCGGCTTGAGATACAAAAAGTTGTACAATCAGGCGAGA 780
HR P nucl. TCTCATAAAGAGGCCATCCTGCTCGGTCTGAGGTACAAAAAGTTGTACAATCAGGCGAGA
M2 P nucl. ....
M3 P nucl. TCTCATAAAGAGGCCATCCTGCTCGGTCTGAGGTACAAAAAGTTGTACAATCAGGCGAGA
M4 P nucl. TCTCATAAAGAGGCCATCCTGCTCGGTCTGAGGTACAAAAAGTTGTACAATCAGGCGAGA

781
GenBank P nucl. GTCAAATATTCTCTGTAG 798
HR P nucl. GTCAAATATTCTCTGTAG
M2 P nucl. ....
M3 P nucl. GTCAAATATTCTCTGTAG
M4 P nucl. GTCAAATATTCTCTGTAG

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FIGURE 16-2



		1	60
GenBank	P a . a .	MDNLT KVREYLKSYSRLDQAVGEIDEIEAQRAEKS NYELFQEDGV EEHTRPSYFQAADDS	
	HR	P a . a .	MDNLT KVREYLKSYSRLDQAVGEIDEIEAQRAEKS NYELFQEDGV EEHTRPSYFQAADDS
	M2	P a . a .	MDNLT KVREYLKSYSRLDQAVGEIDEIEAQRAEKS NYELFQEDGV EEHTRPSYFQAADDS
	M3	P a . a .	MDNLT KVREYLKSYSRLDQAVGEIDEIEAQRAEKS NYELFQEDGV EEHTRPSYFQAADDS
	M4	P a . a .	MDNLT KVREYLKSYSRLDQAVGEIDEIEAQRAEKS NYELFQEDGV EEHTRPSYFQAADDS
		61	120
GenBank	P a . a .	DTESEPEIEDNQGLYVDPPEAEQVEGFIQG PLDDYADEVDVVF TSDWKQPELESDEHGK	
	HR	P a . a .	DTESEPEIEDNQGLYVDPPEAEQVEGFIQG PLDDYADEVDVVF TSDWKQPELESDEHGK
	M2	P a . a .	DTESEPEIEDNQGLYVDPPEAEQVEGFIQG PLDDYADEVDVVF TSDWKQPELESDEHGK
	M3	P a . a .	DTESEPEIEDNQGLYVDPPEAEQVEGFIQG PLDDYADEVDVVF TSDWKQPELESDEHGK
	M4	P a . a .	DTESEPEIEDNQGLYVDPPEAEQVEGFIQG PLDDYADEVDVVF TSDWKQPELESDEHGK
		121	180
GenBank	P a . a .	TLRLT SPEGLS GEQKSQWLSTIKAVVQSAKWNLAECTFEASGEGVIMK ERQITPDVYKV	
	HR	P a . a .	TLRLT SPEGLS GEQKSQWLSTIKAVVQSAKWNLAECTFEASGEGVIMK ERQITPDVYKV
	M2	P a . a .	TLRLT SPEGLS GEQKSQWLSTIKAVVQSAKWNLAECTFEASGEGVIMK ERQITPDVYKV
	M3	P a . a .	TLRLT SPEGLS GEQKSQWLSTIKAVVQSAKWNLAECTFEASGEGVIMK ERQITPDVYKV
	M4	P a . a .	TLRLT SPEGLS GEQKSQWLSTIKAVVQSAKWNLAECTFEASGEGVIMK ERQITPDVYKV
		181	240
GenBank	P a . a .	TPVMNTHPSQSEAVSDVWSLSKTSMTFQPKKASLQPLTISLDEL FSSRGEFISVGGNGRM	
	HR	P a . a .	TPVMNTHPSQSEAVSDVWSLSKTSMTFQPKKASLQPLTISLDEL FSSRGEFISVGGNGRM
	M2	P a . a .	TPVMNTHPSQ . . . . .
	M3	P a . a .	TPVMNTHPSQSEAVSDVWSLSKTSMTFQPKKASLQPLTISLDEL FSSRGEFISVGGNGRM
	M4	P a . a .	TPVMNTHPSQSEAVSDVWSLSKTSMTFQPKKASLQPLTISLDEL FSSRGEFISVGGNGRM
		241	266
GenBank	P a . a .	SHKEA ILLGLRYKKLYNQARVKYSL	
	HR	P a . a .	SHKEA ILLGLRYKKLYNQARVKYSL
	M2	P a . a .	. . . . .
	M3	P a . a .	SHKEA ILLGLRYKKLYNQARVKYSL
	M4	P a . a .	SHKEA ILLGLRYKKLYNQARVKYSL

FIGURE 17



		1	60
GenBank	M nucl.	ATGAGTTCCTTAAAGAAGATTCTCGGTCTGAAGGGGAAAAGGTAAGAAATCTAAGAAATTA	
	HR M nucl.	ATGAGTTCCTTAAAGAAGATTCTCGGTCTGAAGGGGAAAAGGTAAGAAATCTAAGAAATTA	
	M3 M nucl.	ATGAGTTCCTTAAAGAAGATTCTCGGTCTGAAGGGGAAAAGGTAAGAAATCTAAGAAATTA	
	M4 M nucl.	ATGAGTTCCTTAAAGAAGATTCTCGGTCTGAAGGGGAAAAGGTAAGAAATCTAAGAAATTA	
		61	120
GenBank	M nucl.	GGGATCGCACCACCCCTTATGAAGAGGACACTACCATGGAGTATGCTCCGAGCGCTCCA	
	HR M nucl.	GGGATCGCACCACCCCTTATGAAGAGGACACTAACATGGAGTATGCTCCGAGCGCTCCA	
	M3 M nucl.	GGGATCGCACCACCCCTTATGAAGAGGACACTAACATGGAGTATGCTCCGAGCGCTCCA	
	M4 M nucl.	GGGATCGCACCACCCCTTATGAAGAGGACACTAACATGGAGTATGCTCCGAGCGCTCCA	
		121	180
GenBank	M nucl.	ATTGACAAATCCTATTTTGGAGTTGACGAGATGGACACCTATGATCCGAAATCAATTAAGA	
	HR M nucl.	ATTGACAAATCCTATTTTGGAGTTGACGAGATGGACACTCATGATCCGCATCAATTAAGA	
	M3 M nucl.	ATTGACAAATCCTATTTTGGAGTTGACGAGATGGACACTCATGATCCGCATCAATTAAGA	
	M4 M nucl.	ATTGACAAATCCTATTTTGGAGTTGACGAGATGGACACTCATGATCCGCATCAATTAAGA	
		181	240
GenBank	M nucl.	TATGAGAAATTCTTCTTTACAGTGAAAATGACGGTTAGATCTAATCGTCCGTTTCAAGAACA	
	HR M nucl.	TATGAGAAATTCTTCTTTACAGTGAAAATGACGGTTAGATCTAATCGTCCGTTTCAAGAACA	
	M3 M nucl.	TATGAGAAATTCTTCTTTACAGTGAAAATGACGGTTAGATCTAATCGTCCGTTTCAAGAACA	
	M4 M nucl.	TATGAGAAATTCTTCTTTACAGTGAAAATGACGGTTAGATCTAATCGTCCGTTTCAAGAACA	
		241	300
GenBank	M nucl.	TACTCAGATGTGGCAGCCGCTGTATCCCATTTGGGATCACATGTACATCGGAATGGCAGGG	
	HR M nucl.	TACTCAGATGTGGCAGCCGCTGTATCCCATTTGGGATCACATGTACATCGGAATGGCAGGG	
	M3 M nucl.	TACTCAGATGTGGCAGCCGCTGTATCCCATTTGGGATCACATGTACATCGGAATGGCAGGG	
	M4 M nucl.	TACTCAGATGTGGCAGCCGCTGTATCCCATTTGGGATCACATGTACATCGGAATGGCAGGG	
		301	360
GenBank	M nucl.	AAACGTCCCTTCTACAAATCTTTGGCTTTTTTGGGTTCTTCTAATCTAAAGGCCACTCCA	
	HR M nucl.	AAACGTCCCTTCTACAAAGATCTTTGGCTTTTTTGGGTTCTTCTAATCTAAAGGCCACTCCA	
	M3 M nucl.	AAACGTCCCTTCTACAAAGATCTTTGGCTTTTTTGGGTTCTTCTAATCTAAAGGCCACTCCA	
	M4 M nucl.	AAACGTCCCTTCTACAAAGATCTTTGGCTTTTTTGGGTTCTTCTAATCTAAAGGCCACTCCA	
		361	420
GenBank	M nucl.	GCGGTATTGGCAGATCAAGGTCAACCAGAGTATCACACTACTGCGAAGGCAGGGCTTAT	
	HR M nucl.	GCGGTATTGGCAGATCAAGGTCAACCAGAGTATCACGCTCACTGTGAAGGCAGGGCTTAT	
	M3 M nucl.	GCGGTATTGGCAGATCAAGGTCAACCAGAGTATCACGCTCACTGTGAAGGCAGGGCTTAT	
	M4 M nucl.	GCGGTATTGGCAGATCAAGGTCAACCAGAGTATCACGCTCACTGTGAAGGCAGGGCTTAT	
		421	480
GenBank	M nucl.	TTGCCACATAGCATGGGGAAGACCCCTCCCATGCTCAATGTACCAGAGCACTTCAGAAGA	
	HR M nucl.	TTGCCACACAGAATGGGGAAGACCCCTCCCATGCTCAATGTACCAGAGCACTTCAGAAGA	
	M3 M nucl.	TTGCCACACAGAATGGGGAAGACCCCTCCCATGCTCAATGTACCAGAGCACTTCAGAAGA	
	M4 M nucl.	TTGCCACACAGAATGGGGAAGACCCCTCCCATGCTCAATGTACCAGAGCACTTCAGAAGA	
		481	540
GenBank	M nucl.	CCATTCAATATAGGTCTTTACAAGGGAACGATTGAGCTCACAATGACCATCTACGATGAT	
	HR M nucl.	CCATTCAATATAGGTCTTTACAAGGGAACGGTTGAGCTCACAATGACCATCTACGATGAT	
	M3 M nucl.	CCATTCAATATAGGTCTTTACAAGGGAACGGTTGAGCTCACAATGACCATCTACGATGAT	
	M4 M nucl.	CCATTCAATATAGGTCTTTACAAGGGAACGGTTGAGCTCACAATGACCATCTACGATGAT	

FIGURE 18-1



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541
GenBank M nucl. GAGTCACTGGAAGCAGCTCCTATGATCTGGGATCATTTC AATTCTTCCAAATTTTCTGAT 600
HR M nucl. GAGTCACTGGAAGCAGCTCCTATGATCTGGGATCATTTC AATTCTTCCAAATTTTCTGAT
M3 M nucl. GAGTCACTGGAAGCAGCTCCTATGATCTGGGATCATTTC AATTCTTCCAAATTTTCTGAT
M4 M nucl. GAGTCACTGGAAGCAGCTCCTATGATCTGGGATCATTTC AATTCTTCCAAATTTTCTGAT

601
GenBank M nucl. TTCAGAGAGAAGGCCTTAATGTTTGGCCTGATTGTCGAGAAAAAGGCATCTGGAGC GTGG 660
HR M nucl. TTCAGAGAGAAGGCCTTAATGTTTGGCCTGATTGTCGAGAAAAAGGCATCTGGAGCTTGG
M3 M nucl. TTCAGAGAGAAGGCCTTAATGTTTGGCCTGATTGTCGAGAAAAAGGCATCTGGAGCTTGG
M4 M nucl. TTCAGAGAGAAGGCCTTAATGTTTGGCCTGATTGTCGAGAAAAAGGCATCTGGAGCTTGG

661
GenBank M nucl. GTCCTGGATTCTGT CAGCCACTTCAAATGA 690
HR M nucl. GTCCTGGATTCTGT CAGCCACTTCAAATGA
M3 M nucl. GTCCTGGATTCTGT CAGCCACTTCAAATGA
M4 M nucl. GTCCTGGATTCTGT CAGCCACTTCAAATGA
```

FIGURE 18-2



		1		60
GenBank	M a . a .	MSSLKKILGLKGKGKKS	SKKLGIAPPPYEEDT	SMEYAPSAPIDKSYFGVDEMDT
	HR	M a . a .	MSSLKKILGLKGKGKKS	SKKLGIAPPPYEEDTNMEYAPSAPIDKSYFGVDEMDTHDPHQLR
	M4	M a . a .	MSSLKKILGLKGKGKKS	SKKLGIAPPPYEEDTNMEYAPSAPIDKSYFGVDEMDTHDPHQLR
	M3	M a . a .	MSSLKKILGLKGKGKKS	SKKLGIAPPPYEEDTNMEYAPSAPIDKSYFGVDE
			SDTHDPHQLR	
		61		120
GenBank	M a . a .	YEKFFFTVKMTVRSNRPFRTYSDVAAAVSHWDHMYIGMAGKRPFYKILAF	LGSSNLKATP	
	HR	M a . a .	YEKFFFTVKMTVRSNRPFRTYSDVAAAVSHWDHMYIGMAGKRPFYKILAF	LGSSNLKATP
	M4	M a . a .	YEKFFFTVKMTVRSNRPFRTYSDVAAAVSHWDHMYIGMAGKRPFYKILAF	LGSSNLKATP
	M3	M a . a .	YEKFFFTVKMTVRSNRPFRTYSDVAAAVSHWDHMYIGMAGKRPFYKILAF	LGSSNLKATP
		121		180
GenBank	M a . a .	AVLADQGGQPEYH	HCEGRAYLPHRMGKTPPMLNVPEHFRRPFNIGLYKGT	ELTMTIYDD
	HR	M a . a .	AVLADQGGQPEYHAHCEGRAYLPHRMGKTPPMLNVPEHFRRPFNIGLYKGT	VELTMTIYDD
	M4	M a . a .	AVLADQGGQPEYHAHCEGRAYLPHRMGKTPPMLNVPEHFRRPFNIGLYKGT	VELTMTIYDD
	M3	M a . a .	AVLADQGGQPEYHAHCEGRAYLPHRMGKTPPMLNVPEHFRRPFNIGLYKGT	VELTMTIYDD
		181		230
GenBank	M a . a .	ESLEAAPMIWDHFNSSKFSDFREKALMFGLIVEKKASGAWVLD	SVSHFK.	
	HR	M a . a .	ESLEAAPMIWDHFNSSKFSDFREKALMFGLIVEKKASGAWVLD	SVSHFK.
	M4	M a . a .	ESLEAAPMIWDHFNSSKFSDFREKALMFGLIVEKKASGAWVLD	SVSHFK.
	M3	M a . a .	ESLEAAPMIWDHFNSSKFSDFREKALMFGLIVEKKASGAWVLD	SVSHFK.

FIGURE 19



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1                                     60
GenBank G nucl. ATGAAGTGCCTTTTGTACTTAGCTTTTATTTCATGGGGTGAATTGCAAGTTCACCATA
HR G nucl. ATGAAGTGCCTTTTGTACTTAGCTTTTATTTCATCGGGGTGAATTGCAAGTTCACCATA
M2 G nucl. ....
M3 G nucl. ATGAAGTGCCTTTTGTACTTAGCTTTTATTTCATCGGGGTGAATTGCAAGTTCACCATA
M4 G nucl. ATGAAGTGCCTTTTGTACTTAGCTTTTATTTCATCGGGGTGAATTGCAAGTTCACCATA

61                                     120
GenBank G nucl. GTTTTTCACACAACCAAAAAGGAACTGGAAAAATGTTCCCTTCAATTACCATTATTGC
HR G nucl. GTTTTTCATACAACCAAAAAGGAACTGGAAAAATGTTCCCTCCAATTACCATTATTGC
M2 G nucl. ....
M3 G nucl. GTTTTTCATACAACCAAAAAGGAACTGGAAAAATGTTCCCTCCAATTACCATTATTGC
M4 G nucl. GTTTTTCATACAACCAAAAAGGAACTGGAAAAATGTTCCCTCCAATTACCATTATTGC

121                                    180
GenBank G nucl. CCGTCAAGCTCAGATTTAAATTGGCATAATGACTTAATAGGCACAGCCATACAAGTCAAA
HR G nucl. CCGTCAAGCTCAGATTTAAATTGNCATAATGACTTAATAGGCACAGCCTTACAAGTCAAA
M2 G nucl. ....
M3 G nucl. CCGTCAAGCTCAGATTTAAATTGGCATAATGACTTAATAGGCACAGCCTTACAAGTCAAA
M4 G nucl. CCGTCAAGCTCAGATTTAAATTGGCATAATGACTTAATAGGCACAGCCTTACAGTCAAA

181                                    240
GenBank G nucl. ATGCCCCAAGAGTCACAAGGCTATTCAAGCAGACGGTTGGATGTGTCATGCTTCCAAATGG
HR G nucl. ATGCCCCAAGAGTCACAAGGCTATTCAAGCAGACGGTTGGATGTGTCATGCTTCCAAATGG
M2 G nucl. ....
M3 G nucl. ATGCCCCAAGAGTCACAAGGCTATTCAAGCAGACGGTTGGATGTGTCATGCTTCCAAATGG
M4 G nucl. ATGCCCCAAGAGTCACAAGGCTATTCAAGCAGACGGTTGGATGTGTCATGCTTCCAAATGG

241                                    300
GenBank G nucl. GTCACTACTTGTGATTTCCGCTGGTATGGACCGAAGTATATAACACATCCATCCGATCC
HR G nucl. GTCACTACTTGTGATTTCCGCTGGTACGGACCGAAGTATATAACACATCCATCCGATCC
M2 G nucl. ....
M3 G nucl. GTCACTACTTGTGATTTCCGCTGGTACGGACCGAAGTATATAACACATCCATCCGATCC
M4 G nucl. GTCACTACTTGTGATTTCCGCTGGTACGGACCGAAGTATATAACACATCCATCCGATCC

301                                    360
GenBank G nucl. TTCACTCCATCTGTAGAACAATGCAAGGAAAGCATTGAACAAACGAAACAAGGAACCTGG
HR G nucl. TTCACTCCATCTGTAGAACAATGCAAGGAAAGCATTGAACAAACGAAACAAGGAACCTGG
M2 G nucl. ....
M3 G nucl. TTCACTCCATCTGTAGAACAATGCAAGGAAAGCATTGAACAAACGAAACAAGGAACCTGG
M4 G nucl. TTCACTCCATCTGTAGAACAATGCAAGGAAAGCATTGAACAAACGAAACAAGGAACCTGG

361                                    420
GenBank G nucl. CTGAATCCAGGCTTCCCTCCTCAAAGTTGTGGATATGCAACTGTGACGGATGCTGAAGCA
HR G nucl. CTGAATCCAGGCTTCCCTCCTCAAAGTTGTGGATATGCAACTGTGACGGATGCTGAAGCA
M2 G nucl. ....
M3 G nucl. CTGAATCCAGGCTTCCCTCCTCAAAGTTGTGGATATGCAACTGTGACGGATGCTGAAGCA
M4 G nucl. CTGAATCCAGGCTTCCCTCCTCAAAGTTGTGGATATGCAACTGTGACGGATGCTGAAGCA

421                                    480
GenBank G nucl. GTGATTGTCCAGGTGACTCCTCACCATGTGCTGTTGATGAATACACAGGAGAATGGGTT
HR G nucl. GCGATTGTCCAGGTGACTCCTCACCATGTGCTTGTGATGAATACACAGGAGAATGGGTT
M2 G nucl. ....
M3 G nucl. GCGATTGTCCAGGTGACTCCTCACCATGTGCTTGTGATGAATACACAGGAGAATGGGTT
M4 G nucl. GCGATTGTCCAGGTGACTCCTCACCATGTGCTTGTGATGAATACACAGGAGAATGGGTT

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FIGURE 20-1



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481                                     540
GenBank G nucl. GATTCACAGTTCATCAACGGAAAATGCAGCAATACATATGCCCCACTGTCCATAACTCC
HR G nucl. GATTCACAGTTCATCAACGGAAAATGCAGCAATGACATATGCCCCACTGTCCATAACTCC
M2 G nucl. .....
M3 G nucl. GATTCACAGTTCATCAACGGAAAATGCAGCAATGACATATGCCCCACTGTCCATAACTCC
M4 G nucl. GATTCACAGTTCATCAACGGAAAATGCAGCAATGACATATGCCCCACTGTCCATAACTCC

541                                     600
GenBank G nucl. ACAACCTGGCATTCCGACTATAAGGTCAAAGGGCTATGTGATTCTAACCTCATTTCATG
HR G nucl. ACAACCTGGCATTCCGACTATAAGGTCAAAGGGCTATGTGATTCTAACCTCATTTCATG
M2 G nucl. .....
M3 G nucl. ACAACCTGGCATTCCGACTATAAGGTCAAAGGGCTATGTGATTCTAACCTCATTTCATG
M4 G nucl. ACAACCTGGCATTCCGACTATAAGGTCAAAGGGCTATGTGATTCTAACCTCATTTCATG

601                                     660
GenBank G nucl. GACATCACCTTCTTCTCAGAGGACGGAGAGCTATCATCCCTGGAAAGGAGGGGCACAGGG
HR G nucl. GACATCACCTTCTTCTCAGAGGACGGAGAGCTATCATCCCTAGGAAAGGAGGGGCACAGGG
M2 G nucl. .....
M3 G nucl. GACATCACCTTCTTCTCAGAGGACGGAGAGCTATCATCCCTAGGAAAGGAGGGGCACAGGG
M4 G nucl. GACATCACCTTCTTCTCAGAGGACGGAGAGCTATCATCCCTAGGAAAGGAGGGGCACAGGG

661                                     720
GenBank G nucl. TTCAGAAGTAACTACTTTTGCTTATGAAACTGGAGCAAGGCCTGCAAATGCAATACTGC
HR G nucl. TTCAGAAGTAACTACTTTTGCTTATGAAACTGGAGACAAGGCCTGCAAATGCAGTACTGC
M2 G nucl. .....
M3 G nucl. TTCAGAAGTAACTACTTTTGCTTATGAAACTGGAGACAAGGCCTGCAAATGCAGTACTGC
M4 G nucl. TTCAGAAGTAACTACTTTTGCTTATGAAACTGGAGACAAGGCCTGCAAATGCAGTACTGC

721                                     780
GenBank G nucl. AAGCAATTGGGGAGTCAGACTCCCATCAGGTGTCTGGTTTCGAGATGGCTGATAAGGATCTC
HR G nucl. AAGCGTTGGGGAGTCAGACTCCCATCAGGTGTCTGGTTTCGAGATGGCTGATAAGGATCTC
M2 G nucl. .....
M3 G nucl. AAGCAATTGGGGAGTCAGACTCCCATCAGGTGTCTGGTTTCGAGATGGCTGATAAGGATCTC
M4 G nucl. AAGCGTTGGGGAGTCAGACTCCCATCAGGTGTCTGGTTTCGATGGCTGATAAGGATCTC

781                                     840
GenBank G nucl. TTTGCTGCAGCCAGATTCCCTGAATGCCCAGAAGGGTCAAGTATCTCTGCTCCATCTCAG
HR G nucl. TTTGCTGCAGCCAGATTCCCTGAATGCCCAGAAGGGTCAAGTATCTCTGCTCCATCTCAG
M2 G nucl. .....CCATCTCAG
M3 G nucl. TTTGCTGCAGCCAGATTCCCTGAATGCCCAGAAGGGTCAAGTATCTCTGCTCCATCTCAG
M4 G nucl. TTTGCTGCAGCCAGATTCCCTGAATGCCCAGAAGGGTCAAGTATCTCTGCTCCATCTCAG

841                                     900
GenBank G nucl. ACCTCAGTGGATGTAAGTCTAATTCAGGACGTTGAGAGGATCTTGGATTATTCCCTCTGC
HR G nucl. ACCTCAGTGGATGTAAGTCTCATTTCAGGACGTTGAGAGGATCTTG.....
M2 G nucl. ACCTCAGTGGATGTAAGTCTCATTTCAGGACGTTGAGAGGATCTTGGATTATTCCCTCTGC
M3 G nucl. ACCTCAGTGGATGTAAGTCTCATTTCAGGACGTTGAGAGGATCTTGGATTATTCCCTCTGC
M4 G nucl. ACCTCAGTGGATGTAAGTCTCATTTCAGGACGTTGAGAGGATCT.....

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FIGURE 20-2



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GenBank G nucl. 901
HR G nucl. CAAGAAACCTGGAGCAAAATCAGAGCGGGTCTTCCAAATCTCTCCAGTGGATCTCAGCTAT 960
M2 G nucl. CAAGAAACCTGGAGCAAAATCAGAGCGGGTCTTCCCATCTCTCCAGTGGATCTCAGCTAT
M3 G nucl. CAAGAAACCTGGAGCAAAATCAGAGCGGGTCTTCCCATCTCTCCAGTGGATCTCAGCTAT
M4 G nucl. CAAGAAACCTGGAGCAAAATCAGAGCGGGTCTTCCCATCTCTCCAGTGGATCTCAGCTAT
.....

GenBank G nucl. 961
HR G nucl. CTTGCTCCTAAAAACCCAGGAACCGGTCCTGCTTTCACCATAATCAATGGTACCCTAAAA 1020
M2 G nucl. CTTGCTCCTAAAAACCCAGGAACCGGTCCTGTCTTTACCATAATCAATGGTACCCTAAAA
M3 G nucl. CTTGCTCCTAAAAACCCAGGAACCGGTCCTGCTTTCACCATAATCAATGGTACCCTAAAA
M4 G nucl. CTTGCTCCTAAAAACCCAGGAACCGGTCCTGCTTTCACCATAATCAATGGTACCCTAAAA
.....

GenBank G nucl. 1021
HR G nucl. TACTTTGAGACCAGATACATCAGAGTCGATATTGCTGCTCCAATCCTCTCAAGAATGGTC 1080
M2 G nucl. TACTTTGAGACCAGATACATCAGAGTCGATATTGCTGCTCCAATCCTCTCAAGAATGGTC
M3 G nucl. TACTTTGAGACCAGATACATCAGAGTCGATATTGCTGCTCCAATCCTCTCAAGAATGGTC
M4 G nucl. TACTTTGAGACCAGATACATCAGAGTCGATATTGCTGCTCCAATCCTCTCAAGAATGGTC
.....

GenBank G nucl. 1081
HR G nucl. GGAATGATCAGTGGAACCTACCACAGAAAGGGAACCTGTGGGATGACTGGGCACCATATGAA 1140
M2 G nucl. GGAATGATCAGTGGAACCTACCACAGAAAGGGAACCTGTGGGATGACTGGGCTCCATATGAA
M3 G nucl. GGAATGATCAGTGGAACCTACCACAGAAAGGGAACCTGTGGGATGACTGGGCTCCATATGAA
M4 G nucl. GGAATGATCAGTGGAACCTACCACAGAAAGGGAACCTGTGGGATGACTGGGCTCCATATGAA
.....

GenBank G nucl. 1141
HR G nucl. GACGTGGAAATTGGACCCAATGGAGTTCTGAGGACCAGTTCAGGATATAAGTTTCCTTTA 1200
M2 G nucl. GACGTGGAAATTGGACCCAATGGAGTTCTGAGGACCAGTTCAGGATATAAGTTTCCTTTA
M3 G nucl. GACGTGGAAATTGGACCCAATGGAGTTCTGAGGACCAGTTCAGGATATAAGTTTCCTTTA
M4 G nucl. GACGTGGAAATTGGACCCAATGGAGTTCTGAGGACCAGTTCAGGATATAAGTTTCCTTTA
.....

GenBank G nucl. 1201
HR G nucl. TAACATGATTGGACATGGTATGTTGGACTCCGATCTTCATCTTAGCTCAAAGGCTCAGGTG 1260
M2 G nucl. TATATGATTGGACATGGTATGTTGGACTCCGATCTTCATCTTAGCTCAAAGGCTCAGGTG
M3 G nucl. TATATGATTGGACATGGTATGTTGGACTCCGATCTTCATCTTAGCTCAAAGGCTCAGGTG
M4 G nucl. TATATGATTGGACATGGTATGTTGGACTCCGATCTTCATCTTAGCTCAAAGGCTCAGGTG
.....

GenBank G nucl. 1261
HR G nucl. TTCGAAACATCCTCACATTCAAGACGCTGCTTCGCAACTTCCTGATGATGAGAGGTTTATTT 1320
M2 G nucl. TTTGAACATCCTCACATTCAAGACGCTGCTTCGCAGCTTCCTGATGATGAGACTTTATTT
M3 G nucl. TTTGAACATCCTCACATTCAAGACGCTGHTCCGCAGCTTCCTGATGATGAGACTTTATTT
M4 G nucl. TTTGAACATCCTCACATTCAAGACGCTGCTTCGCAGCTTCCTGATGATGAGACTTTATTT

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FIGURE 20-3



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1321                                     1380
GenBank G nucl. TTTGGTGATACTGGGCTATCCAAAAATCCAATCGAGCTTGTAGAAGGTTGGTTCAGTAGT
HR G nucl. ....
M2 G nucl. TTTGGTGATACTGGGCTATCCAAAAATCCAATCGAGTTTGTAGAAGGTTGGTTCAGTAGT
M3 G nucl. TTTGGTGATACTGGGCTATCCAAAAATCCAATCGAGTTTGTAGAAGGTTGGTTCAGTAGT
M4 G nucl. TTTGGTGATACTGGGCTATCCAAAAATCCAATCGAGTTTGTAGAAGGTTGGTTCAGTAGT

1381                                     1440
GenBank G nucl. TGGAAAGAGCTCTATTGCCTCTTTTTTCTTTATCATAGGGTTAATCATTGGACTATTCTTG
HR G nucl. ....
M2 G nucl. TGGAAAGAGCTCTATTGCCTCTTTTTTCTTTATCATAGGGTTAATCATTGGACTATTCTTG
M3 G nucl. TGGAAAGAGCTCTATTGCCTCTTTTTTCTTTATCATAGGGTTAATCATTGGACTATTCTTG
M4 G nucl. TGGAAAGAGCTCTATTGCCTCTTTTTTCTTTATCATAGGGTTAATCATTGGACTATTCTTG

1441                                     1500
GenBank G nucl. GTTCTCCGAGTTGGTATCCATCTTTGCATTAAATTAAAGCACACCAAGAAAAGACAGATT
HR G nucl. ....
M2 G nucl. GTTCTCCGAGTTGGTATTTATCTTTGCATTAAATTAAAGCACACCAAGAAAAGACAGATT
M3 G nucl. GTTCTCCGAGTTGGTATTTATCTTTGCATTAAATTAAAGCACACCAAGAAAAGACAGATT
M4 G nucl. GTTCTCCGAGTTGGTATTTATCTTTGCATTAAATTAAAGCACACCAAGAAAAGACAGATT

1501                                     1536
GenBank G nucl. TATACAGACATAGAGATGAACCGACTTGGGAAGTAA
HR G nucl. ....
M2 G nucl. TATACAGACATAGAGATGAACCGACTTGGGAAGTAA
M3 G nucl. TATACAGACATAGAGATGAACCGACTTGGGAAGTAA
M4 G nucl. TATACAGACATAGAGATGAACCGACTTGGGAAGTAA

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FIGURE 20-4



GenBank	G a. a.	1	60
HR	G a. a.	MKCLLYLAFLFIGVNCKFTIVFPINQKGNWKNVPSNYHYCPSSSDLNWHNDLIGTAIQVK	
M2	G a. a.	MKCLLYLAFLFIGVNCKFTIVFPYNQKGNWKNVPSNYHYCPSSSDLNWHNDLIGTALQVK	
M3	G a. a.	.....	
M4	G a. a.	MKCLLYLAFLFIGVNCKFTIVFPYNQKGNWKNVPSNYHYCPSSSDLNWHNDLIGTALQVK	
GenBank	G a. a.	61	120
HR	G a. a.	MPKSHKAIQADGWMCHASKWVTTCDFRWYGPKYITQSIRSFTPSVEQCKESIEQTKQGTW	
M2	G a. a.	MPKSHKAIQADGWMCHASKWVTTCDFRWYGPKYITHSIRSFTPSVEQCKESIEQTKQGTW	
M3	G a. a.	.....	
M4	G a. a.	MPKSHKAIQADGWMCHASKWVTTCDFRWYGPKYITHSIRSFTPSVEQCKESIEQTKQGTW	
GenBank	G a. a.	121	180
HR	G a. a.	LNPGFPPQSCGYATVTDAAEAIVQVTPHHVLVDEYTG EWVDSQFINGKCSNDICPTVHNS	
M2	G a. a.	LNPGFPPQSCGYATVTDAAEAIVQVTPHHVLVDEYTG EWVDSQFINGKCSNDICPTVHNS	
M3	G a. a.	.....	
M4	G a. a.	LNPGFPPQSCGYATVTDAAEAIVQVTPHHVLVDEYTG EWVDSQFINGKCSNDICPTVHNS	
GenBank	G a. a.	181	240
HR	G a. a.	TTWHSYKVKGLCDSNLISMDITFFSEDGELSSLGKEGTGFRSNYFAYETGCKACKMQYC	
M2	G a. a.	TTWHSYKVKGLCDSNLISMDITFFSEDGELSSLGKEGTGFRSNYFAYETGDKACKMQYC	
M3	G a. a.	.....	
M4	G a. a.	TTWHSYKVKGLCDSNLISMDITFFSEDGELSSLGKEGTGFRSNYFAYETGDKACKMQYC	
GenBank	G a. a.	241	300
HR	G a. a.	KHWGVRLPSGVWFEMADKDLFAAARFPECPEGSSISAPSQTSVDVSLIQDVERILDYSLC	
M2	G a. a.	KHWGVRLPSGVWFEMADKDLFAAARFPECPEGSSISAPSQTSVDVSLIQDVERIL.....	
M3	G a. a.	.....PSQTSVDVSLIQDVERILDYSLC	
M4	G a. a.	KHWGVRLPSGVWFEMADKDLFAAARFPECPEGSSISAPSQTSVDVSLIQDVERIL.....	
GenBank	G a. a.	301	360
HR	G a. a.	QETWSKIRAGLPISPVDLSYLAPKNPGTGPAFTIINGTLKYFETRYIRVDIAAPILSRMV	
M2	G a. a.	.....	
M3	G a. a.	QETWSKIRAGLPISPVDLSYLAPKNPGTGPAFTIINGTLKYFETRYIRVDIAAPILSRMV	
M4	G a. a.	.....YFETRYIRVDIAAPILSRMV	
GenBank	G a. a.	361	420
HR	G a. a.	GMISGTTTERELWDDWAPYEDVEIGPNGVLRRTSSGYKFPLYMIGHGMLDSDLHLSSKAQV	
M2	G a. a.	.....	
M3	G a. a.	GMISGTTTERELWDDWAPYEDVEIGPNGVLRRTSSGYKFPLYMIGHGMLDSDLHLSSKAQV	
M4	G a. a.	GMISGTTTERELWDDWAPYEDVEIGPNGVLRRTSSGYKFPLYMIGHGMLDSDLHLSSKAQV	

FIGURE 21-1



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421
GenBank G a.a. FEHPHIQDAASQLPDDESLFFGDTGLSKNPIELVEGWFSWKSSIASFFFIIGLIIGLFL 480
HR G a.a. ....
M2 G a.a. FEHPHIQDAASQLPDDETLFFGDTGLSKNPIEFVEGWFSWKSSIASFFFIIGLIIGLFL
M3 G a.a. FEHPHIQDAKXQLPDDETLFFGDTGLSKNPIEFVEGWFSWKSSIASFFFIIGLIIGLFL
M4 G a.a. FEHPHIQDAASQLPDDETLFFGDTGLSKNPIEFVEGWFSWKSSIASFFFIIGLIIGLFL

481
GenBank G a.a. VLRVGIHLCKIKHTKKRQIYTDIEMNRLGK 512
HR G a.a. ....
M2 G a.a. VLRVGIYLCIKLKHTKKRQIYTDIEMNRLGK
M3 G a.a. VLRVGIYLCIKLKHTKKRQIYTDIEMNRLGK
M4 G a.a. VLRVGIYLCIKLKHTKKRQIYTDIEMNRLGK
```

FIGURE 21-2



GenBank L nucl.	1	60
HR L nucl.	ATGGAAGTCCACGATTTTGAGACCGACGAGTTCAATGATTTCAATGAAGATGACTATGCC	
M2 L nucl.	.....	
M4 L nucl.	ATGGAAGTCCACGATTTTGAGACCGACGAGTTCAATGATTTCAATGAAGATGACTATGCC	
GenBank L nucl.	61	120
HR L nucl.	ACAAGAGAATTCTGAATCCCGATGAGCGCATGACGTACTTGAATCATGCTGATTACAAT	
M2 L nucl.	.....	
M4 L nucl.	ACAAGAGAATTCTGAATCCCGATGAGCGCATGACGTACTTGAATCATGCTGATTACAAT	
GenBank L nucl.	121	180
HR L nucl.	TTGAATTCTCCTCTAATTAGTGATGATATTGACAATTTGATCAGGAAATTCAATTCTCTT	
M2 L nucl.	.....	
M4 L nucl.	TTGAATTCTCCTCTAATTAGTGATGATATTGACAATTTGATCAGGAAATTCAATTCTCTT	
GenBank L nucl.	181	240
HR L nucl.	CCGATTCCCTCGATGTGGGATAGTAAGAACTGGGATGGAGTTCTTGAGATGTTAACATCA	
M2 L nucl.	.....	
M4 L nucl.	CCGATTCCCTCGATGTGGGATAGTAAGAACTGGGATGGAGTTCTTGAGATGTTAACATCA	
GenBank L nucl.	241	300
HR L nucl.	TGTCAAGCCAATCCCATCTCAACATCTCAGATGCATAAATGGATGGGAAGTTGGTTAATG	
M2 L nucl.	.....	
M4 L nucl.	TGTCAAGCCAATCCCATCTCAACATCTCAGATGCATAAATGGATGGGAAGTTGGTTAATG	
GenBank L nucl.	301	360
HR L nucl.	TCTGATAATCATGATGCCAGTCAAGGGTATAGTTTTTTTACATGAAGTGGACAAAGAGGCA	
M2 L nucl.	.....	
M4 L nucl.	TCTGATAATCATGATGCCAGTCAAGGGTATAGTTTTTTTACATGAAGTGGACAAAGAGGCA	
GenBank L nucl.	361	420
HR L nucl.	GAAATAACATTTGACGTGGTGGAGACCTTCATCCGCGGCTGGGGCAACAAACCAATTGAA	
M2 L nucl.	.....	
M4 L nucl.	GAAATAACATTTGACGTGGTGGAGACCTTCATCCGCGGCTGGGGCAACAAACCAATTGAA	
GenBank L nucl.	421	480
HR L nucl.	TACATCAAAAAGGAAAGATGGACTGACTCATTCAAAATTCTCGCTTATTTGTGTCAAAAG	
M2 L nucl.	.....	
M4 L nucl.	TACATCAAAAAGGAAAGATGGACTGACTCATTCAAAATTCTCGCTTATTTGTGTCAAAAG	
GenBank L nucl.	481	540
HR L nucl.	TTTTTGGACTTACACAAGTTGACATTAATCTTAAATGCTGTCTCTGAGGTGGAATTGCTC	
M2 L nucl.	.....	
M4 L nucl.	TTTTTGGACTTACACAAGTTGACATTAATCTTAAATGCTGTCTCTGAGGTGGAATTGCTC	

FIGURE 22-1



GenBank L nucl.	541	600
HR L nucl.	AACTTGCGGAGGACTTTCAAAGGCAAAGTCAGAAGAAGTTCTCATGGAACGAACATATGC	
M2 L nucl.	.....	
M4 L nucl.	AACTTGCGGAGGACTTTCAAAGGCAAAGTCAGAAGAAGTTCTCATGGAACGAACATATGC	
GenBank L nucl.	601	660
HR L nucl.	AGGATTAGGGTTCCCAGCTTGGGTCTACTTTTATTTTTCAGAAGGATGGGCTTACTTCAAG	
M2 L nucl.	.....	
M4 L nucl.	AGGCTTAGGGTTCCCAGCTTGGGTCTACTTTTATTTTTCAGAAGGATGGGCTTACTTCAAG	
GenBank L nucl.	661	720
HR L nucl.	AAACTTGATATTCTAATGGACCGAAACTTTCTGTTAATGGTCAAAGATGTGATTATAGGG	
M2 L nucl.	.....	
M4 L nucl.	AAACTTGATATTCTAATGGACCGAAACTTTCTGTTAATGGTCAAAGATGTGATTATAGGG	
GenBank L nucl.	721	780
HR L nucl.	AGGATGCAAACGGTGCTATCCATGGTATGTAGAATAGACAACCTGTTCTCAGAGCAAGAC	
M2 L nucl.	.....	
M4 L nucl.	AGGATGCAAACGGTGCTATCCATGGTATGTAGAATAGACAACCTGTTCTCAGAGCAAGAC	
GenBank L nucl.	781	840
HR L nucl.	ATCTTCTCCCTTCTAAATATCTACAGAATTGGAGATAAAATTGTGGAGAGGCAGGGAAAT	
M2 L nucl.	.....	
M4 L nucl.	ATCTTCTCCCTTCTAAATATCTACAGAATTGGAGATAAAATTGTGGAGAGGCAGGGAAAT	
GenBank L nucl.	841	900
HR L nucl.	TTTTCTTATGACTTGATTAAAAATGGTGGAACCGATATGCAACTTGAAAGCTGATGAAATTA	
M2 L nucl.	.....	
M4 L nucl.	TTTTCTTATGACTTGATTAAAAATGGTGGAACCGATATGCAACTTGAAAGCTGATGAAATTA	
GenBank L nucl.	901	960
HR L nucl.	GCAAGAGAATCAAGGCCTTTAGTCCCACAATTCCCTCATTTTGAAAATCATATCAAGACT	
M2 L nucl.	.....	
M4 L nucl.	GCAAGAGAATCAAGGCCTTTAGTCCCACAATTCCCTCATTTTGAAAATCATATCAAGACT	
GenBank L nucl.	961	1020
HR L nucl.	TCTGTTGATGAAGGGGCAAAAATTGACCGAGGTATAAGATTCCCTCCATGATCAGATAATG	
M2 L nucl.	.....	
M4 L nucl.	TCTGTTGATGAAGGGGCAAAAATTGACCGAGGTATAAGATTCCCTCCATGATCAGATAATG	

FIGURE 22-2



GenBank L nucl.	1021	1080
HR L nucl.	AGTGTGAAAACAGTGGATCTCACACTGGTGATTTATGGATCGTTCAGACATTGGGGTCAT	
M2 L nucl.	.....CATTTGGGGTCAT	
M4 L nucl.	AGTGTGAAAACAGTGGATCTCACACTGGTGATTTATGGATCGTTCAGACATTGGGGTCAT	
GenBank L nucl.	1081	1140
HR L nucl.	CCTTTTATAGATTATTACACTGGACTAGAAAAATTACATTCCCAAGTAACCATGAAGAAA	
M2 L nucl.	CCTTTTATAGATTATTACGCTGGCTAGAAAAATTACATTCCCAAGTACCATTGAAGAAA	
M4 L nucl.	CCTTTTATAGATTATTACGCTGGACTAGAAAAATTACATTCCCAAGTAACCATGAAGAAA	
GenBank L nucl.	1141	1200
HR L nucl.	GATATTGATGTGTCATATGCAAAAGCACTTGCAAGTGATTTAGCTCGGATTGTTCTATTT	
M2 L nucl.	GATATTGATGTGTCATATGCAAAAGCACTTGCAAGTGATTTAGCTCGGATTGTTCTATTT	
M4 L nucl.	GATATTGATGTGTCATATGCAAAAGCACTTGCAAGTGATTTAGCTCGGATTGTTCTATTT	
GenBank L nucl.	1201	1260
HR L nucl.	CAACAGTTCAATGATCATATAAAAGTGGTTCGTGAATGGAGACTTGCTCCCTCATGATCAT	
M2 L nucl.	CAACAGTTCAATGATCATATAAAAGTGGTTCGTGAATGGAGACTTGCTCCCTCATGATCAT	
M4 L nucl.	CAACAGTTCAATGATCATATAAAAGTGGTTCGTGAATGGAGACTTGCTCCCTCATGATCAT	
GenBank L nucl.	1261	1320
HR L nucl.	CCCTTTAAAAGTCATGTTAAAGAAAAATACATGGCCACAGCTGCTCAAGTTCAAGATTTT	
M2 L nucl.	CCCTTTAAAAGTCATGTTAAAGAAAAATACATGGCCACAGCTGCTCAAGTTCAAGATTTT	
M4 L nucl.	CCCTTTAAAAGTCATGTTAAAGAAAAATACATGGCCACAGCTGCTCAAGTTCAAGATTTT	
GenBank L nucl.	1321	1380
HR L nucl.	GGAGATAAATGGCATGAACTTCCGCTGATTAAATGTTTTGAAATACCCGACTTACTAGAC	
M2 L nucl.	GGAGATAAATGGCATGAACTTCCGCTGATTAAATGTTTTGAAATACCCGACTTACTAGAC	
M4 L nucl.	GGAGATAAATGGCATGAACTTCCGCTGATTAAATGTTTTGAAATACCCGACTTACTAGAC	
GenBank L nucl.	1381	1440
HR L nucl.	CCATCGATAATATACTCTGACAAAAGTCATTCAATGAATAGGTCAGAGGTGTTGAAACAT	
M2 L nucl.	CCATCGATAATATACTCTGACAAAAGTCATTCAATGAATAGGTCAGAGGTGTTGAAACAT	
M4 L nucl.	CCATCGATAATATACTCTGACAAAAGTCATTCAATGAATAGGTCAGAGGTGTTGAAACAT	
GenBank L nucl.	1441	1500
HR L nucl.	GTCCGAATGAATCCGAACACTCCTATCCCTAGTAAAAAGGTGTTGCAGACTATGTTGGAC	
M2 L nucl.	GTCCGAATGAATCCGAACACTCCTATCCCTAGTAAAAAGGTGTTGCAGACTATGTTGGAC	
M4 L nucl.	GTCCGAATGAATCCGAACACTCCTATCCCTAGTAAAAAGGTGTTGCAGACTATGTTGGAC	

FIGURE 22-3



GenBank L nucl.	1501	1560
HR L nucl.	ACAAAGGCTACCAATTGGAAAGAATTTCTTAAAGAGATTGATGAGAAGGGCTTAGATGAT	
M2 L nucl.	ACAAAGGCTACCAATTGGAAAGAATTTCTTAAAGAGATTGATGAGAAGGGCTTAGATGAT	
M4 L nucl.	.....	
	ACAAAGGCTACCAATTGGAAAGAATTTCTTAAAGAGATTGATGAGAAGGGCTTAGATGAT	
GenBank L nucl.	1561	1620
HR L nucl.	GATGATCTAATTATTGGTCTTAAAGGAAAGGAGAGGGAACTGAAGTTGGCAGGTAGATTT	
M2 L nucl.	GATGATCTAATTATTGGTCTTAAAGGAAAGGAGAGGGAACTGAAGTTGGCAGGTAGATTT	
M4 L nucl.	.....	
	GATGATCTAATTATTGGTCTTAAAGGAAAGGAGAGGGAACTGAAGTTGGCAGGTAGATTT	
GenBank L nucl.	1621	1680
HR L nucl.	TTCTCCCTAATGTCTTGGAATTCGAGAATACTTTGTAATTACCGAATATTTGATAAAG	
M2 L nucl.	TTCTCCCTAATGTCTTGGAATTCGAGAATACTTTGTAATTACCGAATATTTGATAAAG	
M4 L nucl.	.....	
	TTCTCCCTAATGTCTTGGAATTCGAGAATACTTTGTAATTACCGAATATTTGATAAAG	
GenBank L nucl.	1681	1740
HR L nucl.	ACTCATTTTCGTCCCTATGTTTAAAGGCCTGACAATGGCGGACGATCTAACTGCAGTCATT	
M2 L nucl.	ACTCATTTTCGTCCCTATGTTTAAAGGCCTGACAATGGCGGACGATCTAACTGCAGTCATT	
M4 L nucl.	.....	
	ACTCATTTTCGTCCCTATGTTTAAAGGCCTGACAATGGCGGACGATCTAACTGCAGTCATT	
GenBank L nucl.	1741	1800
HR L nucl.	AAAAAGATGTTAGATTCCCTCATCCGGCCAAGGATTGAAGTCATATGAGGCAATTTGCATA	
M2 L nucl.	AAAAAGATGTTAGATTCCCTCATCCGGCCAAGGATTGAAGTCATATGAGGCAATTTGCATA	
M4 L nucl.	.....	
	AAAAAGATGTTAGATTCCCTCATCCGGCCAAGGATTGAAGTCATATGAGGCAATTTGCATA	
GenBank L nucl.	1801	1860
HR L nucl.	GCCAATCACATTGATTACGAAAAATGGAATAACCACCAAAGGAAGTTATCAAACGGCCCA	
M2 L nucl.	GCCAATCACATTGATTACGAAAAATGGAATAACCACCAAAGGAAGTTATCAAACGGCCCA	
M4 L nucl.	.....	
	GCCAATCACATTGATTACGAAAAATGGAATAACCACCAAAGGAAGTTATCAAACGGCCCA	
GenBank L nucl.	1861	1920
HR L nucl.	GTGTTCCGAGTTATGGGCCAGTTCTTAGGTTATCCATCCTTAATCGAGAGAACTCATGAA	
M2 L nucl.	GTGTTCCGAGTTATGGGCCAGTTCTTAGGTTATCCATCCTTAATCGAGAGAACTCATGAA	
M4 L nucl.	.....	
	GTGTTCCGAGTTATGGGCCAGTTCTTAGGTTATCCATCCTTAATCGAGAGAACTCATGAA	
GenBank L nucl.	1921	1980
HR L nucl.	TTTTTTGAGAAAAGTCTTATATACTACAATGGAAGACCAGACTTGATGCGTGTTTACAAC	
M2 L nucl.	TTTTTTGAGAAAAGTCTTATATACTACAATGGAAGACCAGACTTGATGCGTGTTTACAAC	
M4 L nucl.	.....	
	TTTTTTGAGAAAAGTCTTATATACTACAATGGAAGACCAGACTTGATGCGTGTTTACAAC	
GenBank L nucl.	1981	2040
HR L nucl.	AACACACTGATCAATTCAACCTCCCAACGAGTTTGTGGCAAGGACAAGAGGGTGACTG	
M2 L nucl.	AACACACTGATCAATTCAACCTCCCAACGAGTTTGTGGCAAGGACAAGAGGGTGACTG	
M4 L nucl.	.....	
	AACACACTGATCAATTCAACCTCCCAACGAGTTTGTGGCAAGGACAAGAGGGTGACTG	

FIGURE 22-4



	2041	2100
GenBank L nucl.	GAAGGTCTACGGCAAAAAGGATGGAGATATCCTCAATCTACTGGTTATTCAAAGAGAGGCT	
HR L nucl.	GAAGGTCTACGGCAAAAAGGATGGAGTATCCTCAATCTACTGGTTATTCAAAGAGAGGCT	
M2 L nucl.	.....	
M4 L nucl.	GAAGGTCTACGGCAAAAAGGATGGAGTATCCTCAATCTACTGGTTATTCAAAGAGAGGCT	
	2101	2160
GenBank L nucl.	AAAATCAGAAACACTGCTGTCAAAGTCTTGGCACAAGGTGATAATCAAGTTATTTGCACA	
HR L nucl.	AAAATCAGAAACACTGCTGTCAAAGTCTTGGCACAAGGTGATAATCAAGTTATTTGCACA	
M2 L nucl.	.....	
M4 L nucl.	AAAATCAGAAACACTGCTGTCAAAGTCTTGGCACAAGGTGATAATCAAGTTATTTGCACA	
	2161	2220
GenBank L nucl.	CAGTATAAAACGAAGAAATCGAGAAACGTTGTAGAATTACAGGGTGCTCTCAATCAAATG	
HR L nucl.	CAGTATAAAACGAAGAAATCGAGAAACGTTGTAGAATTACAGGGTGCTCTCAATCAAATG	
M2 L nucl.	.....	
M4 L nucl.	CAGTATAAAACGAAGAAATCGAGAAACGTTGTAGAATTACAGGGTGCTCTCAATCAAATG	
	2221	2280
GenBank L nucl.	GTTTCTAATAATGAGAAAATTATGACTGCAATCAAATAGGGACAGGGAAGTTAGGACTT	
HR L nucl.	GTTTCTAATAATGAGAAAATTATGACTGCAATCAAATAGGGACAGGGAAGTTAGGACTT	
M2 L nucl.	.....	
M4 L nucl.	GTTTCTAATAATGAGAAAATTATGACTGCAATCAAATAGGGACAGGGAAGTTAGGACTT	
	2281	2340
GenBank L nucl.	TTGATAAATGACGATGAGACTATGCAATCTGCAGATTACTTGAATTATGGAAAAATACCG	
HR L nucl.	TTGATAAATGACGATGAGACTATGCAATCTGCAGATTACTTGAATTATGGAAAAATACCG	
M2 L nucl.	.....	
M4 L nucl.	TTGATAAATGACGATGAGACTATGCAATCTGCAGATTACTTGAATTATGGAAAAATACCGA	
	2341	2400
GenBank L nucl.	ATTTTCCGTGGAGTGATTAGAGGGTTAGAGACCAAGAGATGGTCACGAGTGACTTGTGTC	
HR L nucl.	ATTTTCCGTGGAGTGATTAGAGGGTTAGAGACCAAGAGATGGTCACGAGTGACTTGTGTC	
M2 L nucl.	.....	
M4 L nucl.	ATTTTCCGTGGAGTGATTAGAGGGTTAGAGACCAAGAGATGGTCACGAGTGACTTGTGTC	
	2401	2460
GenBank L nucl.	ACCAATGACCAAATACCCACTTGTGCTAATATAATGAGCTCAGTTTCCACAAATGCTCTC	
HR L nucl.	ACCAATGACCAAATACCCACTTGTGCTAATATAATGAGCTCAGTTTCCACAAATGCTCTC	
M2 L nucl.	.....	
M4 L nucl.	ACCAATGACCAAATACCCACTTGTGCTAATATAATGAGCTCAGTTTCCACAAATGCTCTC	
	2461	2520
GenBank L nucl.	ACCGTAGCTCATTTTGCTGAGAACCCAATCAATGCCATGATACAGTACAATTATTTGGG	
HR L nucl.	ACCGTAGCTCATTTTGCTGAGAACCCAATCAATGCCATGATACAGTACAATTATTTGGG	
M2 L nucl.	.....	
M4 L nucl.	ACCGTAGCTCATTTTGCTGAGAACCCAATCAATGCCATGATACAGTACAATTATTTGGG	
	2521	2580
GenBank L nucl.	ACATTTGCTAGACTCTTGTTGATGATGCATGATCCTGCTCTTCGTCAATCATTGTATGAA	
HR L nucl.	ACATTTGCTAGACTCTTGTTGATGATGCATGATCCTGCTCTTCGTCAATCATTGTATGAA	
M2 L nucl.	.....	
M4 L nucl.	ACATTTGCTAGACTCTTGTTGATGATGCATGATCCTGCTCTTCGTCAATCATTGTATGAA	

FIGURE 22-5



GenBank L nucl.	2581	2640
HR L nucl.	GTTCAAGATAAGATACCGGGCTTGACAGTTCTACTTTCAAATACGCCATGTTGTATTTG	
M2 L nucl.	GTTCAAGATAAGATACCGGGCTTGACAGTTCTACTTTCAAATACGCCATGTTGTATTTG	
M4 L nucl.	.....	
	GTTCAAGATAAGATACCGGGCTTGACAGTTCTACTTTCAAATACGCCATGTTGTATTTG	
GenBank L nucl.	2641	2700
HR L nucl.	GACCCTTCCATTGGAGGAGTGTCTGGGCATGTCTTTGTCCAGGTTTTTGATTAGAGCCTTC	
M2 L nucl.	GACCCTTCCATTGGAGGAGTGTCTGGGCATGTCTTTGTCCAGGTTTTTGATTAGAGCCTTC	
M4 L nucl.	.....	
	GACCCTTCCATTGGAGGAGTGTCTGGGCATGTCTTTGTCCAGGTTTTTGATTAGAGCCTTC	
GenBank L nucl.	2701	2760
HR L nucl.	CCAGATCCCGTAACAGAAAGTCTCTCATTCTGGAGATTCATCCATGTACATGCTCGAAGT	
M2 L nucl.	CCAGATCCCGTAACAGAAAGTCTCTCATTCTGGAGATTCATCCATGTACATGCTCGAAGT	
M4 L nucl.	.....	
	CCAGATCCCGTAACAGAAAGTCTCTCATTCTGGAGATTCATCCATGTACATGCTCGAAGT	
GenBank L nucl.	2761	2820
HR L nucl.	GAGCATCTGAAGGAGATGAGTGCAGTATTTGGAAACCCCGAGATAGCCAAGTTTCGAATA	
M2 L nucl.	GAGCATCTGAAGGAGATGAGTGCAGTATTTGGAAACCCCGAGATAGCCAAGTTTCGAATA	
M4 L nucl.	.....	
	GAGCATCTGAAGGAGATGAGTGCAGTATTTGGAAACCCCGAGATAGCCAAGTTTCGAATA	
GenBank L nucl.	2821	2880
HR L nucl.	ACTCACATAGACAAGCTAGTAGAAGATCCAACCTCTCTGAACATCGCTATGGGAATGAGT	
M2 L nucl.	ACTCACATAGACAAGCTAGTAGAAGATCCAACCTCTCTGAACATCGCTATGGGAATGAGT	
M4 L nucl.	.....	
	ACTCACATAGACAAGCTAGTAGAAGATCCAACCTCTCTGAACATCGCTATGGGAATGAGT	
GenBank L nucl.	2881	2940
HR L nucl.	CCAGCGAACTTGTTAAAGACTGAGGTAAAAAATGCTTAATCGAATCAAGACAAACCATC	
M2 L nucl.	CCAGCGAACTTGTTAAAGACTGAGGTAAAAAATGCTTAATCGAATCAAGACAAACCATC	
M4 L nucl.	.....	
	CCAGCGAACTTGTTAAAGACTGAGGTAAAAAATGCTTAATCGAATCAAGACAAACCATC	
GenBank L nucl.	2941	3000
HR L nucl.	AGGAACCAGGTGATTAAGGATGCAACCATATATTTGTATCATGAAGAGGATCGGCTCAGA	
M2 L nucl.	AGGAACCAGGTGATTAAGGATGCAACCATATATTTGTATCATGAAGAGGATCGGCTCAGA	
M4 L nucl.	.....	
	AGGAACCAGGTGATTAAGGATGCAACCATATATTTGTATCATGAAGAGGATCGGCTCAGA	
GenBank L nucl.	3001	3060
HR L nucl.	AGTTTCTTATGGTCAATAAATCCTCTGTTCCCTAGATTTTTTAAGTGAATTCAAATCAGGC	
M2 L nucl.	AGTTTCTTATGGTCAATAAATCCTCTGTTCCCTAGATTTTTTAAGTGAATTCAAATCAGGC	
M4 L nucl.	.....	
	AGTTTCTTATGGTCAATAAATCCTCTGTTCCCTAGATTTTTTAAGTGAATTCAAATCAGGC	
GenBank L nucl.	3061	3120
HR L nucl.	ACTTTTTTGGGAGTCGCAGACGGGCTCATCAGTCTATTTCAAATTTCTCGTACTATTTCGG	
M2 L nucl.	ACTTTTTTGGGAGTCGCAGACGGGCTCATCAGTCTATTTCAAATTTCTCGTACTATTTCGG	
M4 L nucl.	.....	
	ACTTTTTTGGGAGTCGCAGACGGGCTCATCAGTCTATTTCAAATTTCTCGTACTATTTCGG	

FIGURE 22-6



GenBank L nucl.	3121	3180
HR L nucl.	AACTCCTTTAAGAAAAAGTATCATAGGGAATTGGATGATTTGATTGTGAGGAGTGAGGTA	
M2 L nucl.	AACTCCTTTAAGAAAAAGTATCATAGGGAATTGGATGATTTGATTGTGAGGAGTGAGGTA	
M4 L nucl.	AACTCCTTTAAGAAAAAGTATCATAGGGAATTGGATGATTTGATTGTGAGGAGTGAGGTA	
GenBank L nucl.	3181	3240
HR L nucl.	TCCTCTTTGACACATTTAGGGAAACTTCATTTGAGAAGGGGATCATGTAAAATGTGGACA	
M2 L nucl.	TCCTCTTTGACACATTTAGGGAAACTTCATTTGAGAAGGGGATCATGTAAAATGTGGACA	
M4 L nucl.	TCCTCTTTGACACATTTAGGGAAACTTCATTTGAGAAGGGGATCATGTAAAATGTGGACA	
GenBank L nucl.	3241	3300
HR L nucl.	TGTTTCAGCTACTCATGCTGACACATTAAGATACAAATCCTGGGGCCGTACAGTTATTGGG	
M2 L nucl.	TGTTTCAGCTACTCATGCTGACACATTAAGATACAAATCCTGGGGCCGTACAGTTATTGGG	
M4 L nucl.	TGTTTCAGCTACTCATGCTGACACATTAAGATACAAATCCTGGGGCCGTACAGTTATTGGG	
GenBank L nucl.	3301	3360
HR L nucl.	ACAACCTGTACCCCATCCATTAGAAATGTTGGGTCCACAACATCGAAAAGAGACTCCTTGT	
M2 L nucl.	ACAACCTGTACCCCATCCATTAGAAATGTTGGGTCCACAACATCGAAAAGAGACTCCTTGT	
M4 L nucl.	ACAACCTGTACCCCATCCATTAGAAATGTTGGGTCCACAACATCGAAAAGAGACTCCTTGT	
GenBank L nucl.	3361	3420
HR L nucl.	GCACCATGTAACACATCAGGGTTCAATTATGTTTCTGTGCATTGTCCAGACGGGATCCAT	
M2 L nucl.	GCACCATGTAACACATCAGGGTTCAATTATGTTTCTGTGCATTGTCCAGACGGGATCCAT	
M4 L nucl.	GCACCATGTAACACATCAGGGTTCAATTATGTTTCTGTGCATTGTCCAGACGGGATCCAT	
GenBank L nucl.	3421	3480
HR L nucl.	GACGTCTTTAGTTCACGGGGACCATTGCCTGCTTATCTAGGGTCTAAAACATCTGAATCT	
M2 L nucl.	GACGTCTTTAGTTCACGGGGACCATTGCCTGCTTATCTAGGGTCTAAAACATCTGAATCT	
M4 L nucl.	GACGTCTTTAGTTCACGGGGACCATTGCCTGCTTATCTAGGGTCTAAAACATCTGAATCT	
GenBank L nucl.	3481	3540
HR L nucl.	ACATCTATTTTGCAGCCTTGGGAAAGGGAAAGCAAAGTCCCACTGATTAAAAGAGCTACA	
M2 L nucl.	ACATCTATTTTGCAGCCTTGGGAAAGGGAAAGCAAAGTCCCACTGATTAAAAGAGCTACA	
M4 L nucl.	ACATCTATTTTGCAGCCTTGGGAAAGGGAAAGCAAAGTCCCACTGATTAAAAGAGCTACA	
GenBank L nucl.	3541	3600
HR L nucl.	CGTCTTAGAGATGCTATCTCTTGGTTTGTGTAACCCGACTCTAAACTAGCAATGACTATA	
M2 L nucl.	CGTCTTAGAGATGCTATCTCTTGGTTTGTGTAACCCGACTCTAAACTAGCAATGACTATA	
M4 L nucl.	CGTCTTAGAGATGCTATCTCTTGGTTTGTGTAACCCGACTCTAAACTAGCAATGACTATA	
GenBank L nucl.	3601	3660
HR L nucl.	CTTTCTAACATCCACTCTTTAACAGGCGAAGAATGGACCAAAAGGCAGCATGGGTTCAAA	
M2 L nucl.	CTTTCTAACATCCACTCTTTAACAGGCGAAGAATGGACCAAAAGGCAGCATGGGTTCAAA	
M4 L nucl.	CTTTCTAACATCCACTCTTTAACAGGCGAAGAATGGACCAAAAGGCAGCATGGGTTCAAA	

FIGURE 22-7



GenBank L nucl.	3661	3720
HR L nucl.	AGAACAGGGTCTGCCCTTCATAGGTTTTCGACATCTCGGATGAGCCATGGTGGGTTTCGCA	
M2 L nucl.	AGAACAGGGTCTGCCCTTCATAGGTTTTCGACATCTCGGATGAGCCATGGTGGGTTTCGCA	
M4 L nucl.	AGAACAGGGTCTGCCCTTCATAGGTTTTCGACATCTCGGATGAGCCATGGTGGGTTTCGCA	
GenBank L nucl.	3721	3780
HR L nucl.	TCTCAGAGCACTGCAGCATTGACCAGGTTGATGGCAACTACAGACACCATGAGGGATCTG	
M2 L nucl.	TCTCAGAGCACTGCAGCATTGACCAGGTTGATGGCAACTACAGACACCATGAGGGATCTG	
M4 L nucl.	TCTCAGAGCACTGCAGCATTGACCAGGTTGATGGCAACTACAGACACCATGAGGGATCTG	
GenBank L nucl.	3781	3840
HR L nucl.	GGAGATCAGAATTTTCGACTTTTTATTCCAAGCAACGTTGCTCTATGCTCAAATTACCACC	
M2 L nucl.	GGAGATCAGAATTTTCGACTTTTTATTCCAAGCAACGTTGCTCTATGCTCAATTACCACC	
M4 L nucl.	GGAGATCAGAATTTTCGACTTTTTATTCCAAGCAACGTTGCTCTATGCTCAATTACCACC	
GenBank L nucl.	3841	3900
HR L nucl.	ACTGTTGCAAGAGACGGATGGATCACCAGTTGTACAGATCATTATCATATTGCCTGTAAG	
M2 L nucl.	ACTGTTGCAAGAGACGGATGGATCACCAGTTGTACAGATCATTATCATATTGCCTGTAAG	
M4 L nucl.	ACTGTTGCAAGAGACGGATGGATCACCAGTTGTACAGATCATTATCATATTGCCTGTAAG	
GenBank L nucl.	3901	3960
HR L nucl.	TCCTGTTTGAGACCCATAGAAGAGATCACCCCTGGACTCAAGTATGGACTACACGCCCCCA	
M2 L nucl.	TCCTGTTTGAGACCCATAGAAGAGATCACCCCTGGACTCAAGTATGGACTACACGCCCCCA	
M4 L nucl.	TCCTGTTTGAGACCCATAGAAGAGATCACCCCTGGACTCAAGTATGGACTACACGCCCCCA	
GenBank L nucl.	3961	4020
HR L nucl.	GATGTATCCCATGTGCTGAAGACATGGAGGAATGGGGAAGGTTTCGTGGGGACAAGAGATA	
M2 L nucl.	GATGTATCCCATGTGCTGAAGACATGGAGGAATGGGGAAGGTTTCGTGGGGACAAGAGATA	
M4 L nucl.	GATGTATCCCATGTGCTGAAGACATGGAGGAATGGGGAAGGTTTCGTGGGGACAAGAGATA	
GenBank L nucl.	4021	4080
HR L nucl.	AAACAGATCTATCCTTTAGAAAGGGAATTGGAAGAATTTAGCACCTGCTGAGCAATCCTAT	
M2 L nucl.	AAACAGATCTATCCTTTAGAAAGGGAATTGGAAGAATTTAGCACCTGCTGAGCAATCCTAT	
M4 L nucl.	AAACAGATCTATCCTTTAGAAAGGGAATTGGAAGAATTTAGCACCTGCTGAGCAATCCTAT	
GenBank L nucl.	4081	4140
HR L nucl.	CAAGTCGGCAGATGTATAGGTTTTCTATATGGAGACTTGGCGTATAGAAAATCTACTCAT	
M2 L nucl.	CAAGTCGGCAGATGTATAGGTTTTCTATATGGAGACTTGGCGTATAGAAAATCTACTCAT	
M4 L nucl.	CAAGTCGGCAGATGTATAGGTTTTCTATATGGAGACTTGGCGTATAGAAAATCTACTCAT	
GenBank L nucl.	4141	4200
HR L nucl.	GCCGAGGACAGTTCTCTATTTCTCTATCTATACAAGGTCGTATTAGAGGTCGAGGTTTC	
M2 L nucl.	GCCGAGGACAGTTCTCTATTTCTCTATCTATACAAGGTCGTATTAGAGGTCGAGGTTTC	
M4 L nucl.	GCCGAGGACAGTTCTCTATTTCTCTATCTATACAAGGTCGTATTAGAGGTCGAGGTTTC	

FIGURE 22-8



	4201	4260
GenBank L nucl.	TTAAAAGGGTTGCTAGACGGATTAATGAGAGCAAGTTGCTGCCAAGTAATACACCGGAGA	
HR L nucl.	TTAAAAGGGTTGCTAGACGGATTAATGAGAGCAAGTTGCTGCCAAGTAATACACCGGAGA	
M2 L nucl.	.....	
M4 L nucl.	TTAAAAGGGTTGCTAGACGGATTAATGAGAGCAAGTTGCTGCCAAGTAATACACCGGAGA	
	4261	4320
GenBank L nucl.	AGTCTGGCTCATTGGAAGAGGCCGGCCAACGCAGTGACGGAGGTTTGATTTACTTGATT	
HR L nucl.	AGTCTGGCTCATTGGAAGAGGCCGGCCAACGCAGTGACGGAGGTTTGATTTACTTGATT	
M2 L nucl.	.....	
M4 L nucl.	AGTCTGGCTCATTGGAAGAGGCCGGCCAACGCAGTGACGGAGGTTTGATTTACTTGATT	
	4321	4380
GenBank L nucl.	GATAAATTGAGTGTATCACCTCCATTCCCTTCTCTTACTAGATCAGGACCTATTAGAGAC	
HR L nucl.	GATAAATTGAGTGTATCACCTCCATTCCCTTCTCTTACTAGATCAGGACCTATTAGAGAC	
M2 L nucl.	.....	
M4 L nucl.	GATAAATTGAGTGTATCACCTCCATTCCCTTCTCTTACTAGATCAGGACCTATTAGAGAC	
	4381	4440
GenBank L nucl.	GAATTAGAAACGATTCCCCACAAGATCCCAACCTCCTATCCGACAAGCAACCGTGATATG	
HR L nucl.	GAATTAGAAACGATTCCCCACAAGATCCCAACCTCCTATCCGACAAGCAACCGTGATATG	
M2 L nucl.	.....	
M4 L nucl.	GAATTAGAAACGATTCCCCACAAGATCCCAACCTCCTATCCGACAAGCAACCGTGATATG	
	4441	4500
GenBank L nucl.	GGGGTGATTGTCAGAAATTACTTCAAATACCAATGCCGTCTAATTGAAAAGGGAAAATAC	
HR L nucl.	GGGGTGATTGTCAGAAATTACTTCAAATACCAATGCCGTCTAATTGAAAAGGGAAAATAC	
M2 L nucl.	.....	
M4 L nucl.	GGGGTGATTGTCAGAAATTACTTCAAATACCAATGCCGTCTAATTGAAAAGGGAAAATAC	
	4501	4560
GenBank L nucl.	AGATCACATTATTACAAATTATGGTTATTCTCAGATGTCTTATCCATAGACTTCATTGGA	
HR L nucl.	AGATCACATTATTACAAATTATGGTTATTCTCAGATGTCTTATCCATAGACTTCATTGGA	
M2 L nucl.	.....	
M4 L nucl.	AGATCACATTATTACAAATTATGGTTATTCTCAGATGTCTTATCCATAGACTTCATTGGA	
	4561	4620
GenBank L nucl.	CCATTCTCTATTTCCACCACCCTCTTGCAAATCCTATACAAGCCATTTTATCTGGGAAA	
HR L nucl.	CCATTCTCTATTTCCACCACCCTCTTGCAAATCCTATACAAGCCATTTTATCTGGGAAA	
M2 L nucl.	.....	
M4 L nucl.	CCATTCTCTATTTCCACCACCCTCTTGCAAATCCTATACAAGCCATTTTATCTGGGAAA	
	4621	4680
GenBank L nucl.	GATAAGAATGAGTTGAGAGAGCTGGCAAATCTTTCTTCATTGCTAAGATCAGGAGAGGGG	
HR L nucl.	GATAAGAATGAGTTGAGAGAGCTGGCAAATCTTTCTTCATTGCTAAGATCAGGAGAGGGG	
M2 L nucl.	.....	
M4 L nucl.	GATAAGAATGAGTTGAGAGAGCTGGCAAATCTTTCTTCATTGCTAAGATCAGGAGAGGGG	
	4681	4740
GenBank L nucl.	TGGGAAGACATACATGTGAAATTCTTCACCAAGGACATATTATTGTGTCCAGAGGAAATC	
HR L nucl.	TGGGAAGACATACATGTGAAATTCTTCACCAAGGACATATTATTGTGTCCAGAGGAAATC	
M2 L nucl.	.....	
M4 L nucl.	TGGGAAGACATACATGTGAAATTCTTCACCAAGGACATATTATTGTGTCCAGAGGAAATC	

FIGURE 22-9



GenBank L nucl.	4741	4800
HR L nucl.	AGACATGCTTGCAAGTTCGGGATTGCTAAGGATAATAATAAAGACATGAGCTATCCCCCT	
M2 L nucl.	AGACATGCTTGCAAGTTCGGGATTGCTAAGGATAATAATAAAGACATGAGCTATCCCCCT	
M4 L nucl.	.....	
	AGACATGCTTGCAAGTTCGGGATTGCTAAGGATAATAATAAAGACATGAGCTATCCCCCT	
GenBank L nucl.	4801	4860
HR L nucl.	TGGGGAAGGGAATCCAGAGGGACAATTACAACAATCCCTGTTTATTATACGACCACCCCT	
M2 L nucl.	TGGGGAAGGGAATCCAGAGGGACAATTACAACAATCCCTGTTTATTATACGACCACCCCT	
M4 L nucl.	.....	
	TGGGGAAGGGAATCCAGAGGGACAATTACAACAATCCCTGTTTATTATACGACCACCCCT	
GenBank L nucl.	4861	4920
HR L nucl.	TACCCAAAGATGCTAGAGATGCCTCCAAGAATCCAAAATCCCCTGCTGTCCGGAATCAGG	
M2 L nucl.	TACCCAAAGATGCTAGAGATGCCTCCAAGAATCCAAAATCCCCTGCTGTCCGGAATCAGG	
M4 L nucl.	.....	
	TACCCAAAGATGCTAGAGATGCCTCCAAGAATCCAAAATCCCCTGCTGTCCGGAATCAGG	
GenBank L nucl.	4921	4980
HR L nucl.	TTGGGCCCAATTACCAACTGGCGCTCATTATAAAATTCGGAGTATATTACATGGAATGGGA	
M2 L nucl.	TTGGGCCAGTTACCAACTGGCGCTCATTATAAAATTCGGAGTATATTACATGGAATGGGA	
M4 L nucl.	.....	
	TTGGGCCAGTTACCAACTGGCGCTCATTATAAAATTCGGAGTATATTACATGGAATGGGA	
GenBank L nucl.	4981	5040
HR L nucl.	ATCCATTACAGGGACTTCTTGAGTTGTGGAGACGGCTCCGGAGGGATGACTGCTGCATTA	
M2 L nucl.	ATCCATTACAGGGACTTCTTGAGTTGTGGAGACGGCTCCGGAGGGATGACTGCTGCATTA	
M4 L nucl.	.....	
	ATCCATTACAGGGACTTCTTGAGTTGTGGAGACGGCTCCGGAGGGATGACTGCTGCATTA	
GenBank L nucl.	5041	5100
HR L nucl.	CTACGAGAAAATGTGCATAGCAGAGGAATATTCAATAGTCTGTTAGAATTATCAGGGTCA	
M2 L nucl.	CTACGAGAAAATGTGCATAGCAGAGGAATATTCAATAGTCTGTTAGAATTATCAGGGTCA	
M4 L nucl.	.....	
	CTACGAGAAAATGTGCATAGCAGAGGAATATTCAATAGTCTGTTAGAATTATCAGGGTCA	
GenBank L nucl.	5101	5160
HR L nucl.	GTCATGCGAGGCGCCTCTCCTGAGCCCCCAGTGCCCTAGAAACTTTAGGAGGAGATAAA	
M2 L nucl.	GTCATGCGAGGCGCCTCTCCTGAGCCCCCAGTGCCCTAGAAACTTTAGGAGGAGATAAA	
M4 L nucl.	.....	
	GTCATGCGAGGCGCCTCTCCTGAGCCCCCAGTGCCCTAGAAACTTTAGGAGGAGATAAA	
GenBank L nucl.	5161	5220
HR L nucl.	TCGAGATGTGTAAATGGTGAAACATGTTGGGAATATCCATCTGACTTATGTGACCCAAGG	
M2 L nucl.	TCGAGATGTGTAAATGGTGAAACATGTTGGGAATATCCATCTGACTTATGTGACCCAAGG	
M4 L nucl.	.....	
	TCGAGATGTGTAAATGGTGAAACATGTTGGGAATATCCATCTGACTTATGTGACCCAAGG	
GenBank L nucl.	5221	5280
HR L nucl.	ACTTGGGACTATTTCCCTCCGACTCAAAGCAGGCTTGGGGCTTCAAATTGATTTAATTGTA	
M2 L nucl.	ACTTGGGACTATTTCCCTCCGACTCAAAGCAGGCTTGGGGCTTCAAATTGATTTAATTGTA	
M4 L nucl.	.....	
	ACTTGGGACTATTTCCCTCCGACTCAAAGCAGGCTTGGGGCTTCAAATTGATTTAATTGTA	

FIGURE 22-10



GenBank L nucl.	5281	5340
HR L nucl.	ATGGATATGGAAGTTCGGGATTCTTCTACTAGCCTGAAAATTGAGACGAATGTTAGAAAT	
M2 L nucl.	ATGGATATGGAAGTTCGGGATTCTTCTACTAGCCTGAAAATTGAGACGAATGTTAGAAAT	
M4 L nucl.	.....	
	ATGGATATGGAAGTTCGGGATTCTTCTACTAGCCTGAAAATTGAGACGAATGTTAGAAAT	
GenBank L nucl.	5341	5400
HR L nucl.	TATGTGCACCGGATTTTGGATGAGCAAGGAGTTTAAATCTACAAGACTTATGGAACATAT	
M2 L nucl.	TATGTGCACCGGATTTTGGATGAGCAAGGAGTTTAAATCTACAAGACTTATGGAACATAT	
M4 L nucl.	.....	
	TATGTGCACCGGATTTTGGATGAGCAAGGAGTTTAAATCTACAAGACTTATGGAACATAT	
GenBank L nucl.	5401	5460
HR L nucl.	ATTTGTGAGAGCGAAAAGAATGCAGTAACAATCCTTGGTCCCATGTTCAAGACGGTCGAC	
M2 L nucl.	ATTTGTGAGAGCGAAAAGAATGCAGTAACAATCCTTGGTCCCATGTTCAAGACGGTCGAC	
M4 L nucl.	.....	
	ATTTGTGAGAGCGAAAAGAATGCAGTAACAATCCTTGGTCCCATGTTCAAGACGGTCGAC	
GenBank L nucl.	5461	5520
HR L nucl.	TTAGTTCAAACAGAATTTAGTAGTTCTCAAACGTCTGAAGTATATATGGTATGTAAAGGT	
M2 L nucl.	TTAGTTCAAACAGAATTTAGTAGTTCTCAAACGTCTGAAGTATATATGGTATGTAAAGGT	
M4 L nucl.	.....	
	TTAGTTCAAACAGAATTTAGTAGTTCTCAAACGTCTGAAGTATATATGGTATGTAAAGGT	
GenBank L nucl.	5521	5580
HR L nucl.	TTGAAGAAATTAATCGATGAACCCAATCCCGATTGGTCTTCCATCAATGAATCCTGGAAA	
M2 L nucl.	TTGAAGAAATTAATCGATGAACCCAATCCCGATTGGTCTTCCATCAATGAATCCTGGAAA	
M4 L nucl.	.....	
	TTGAAGAAATTAATCGATGAACCCAATCCCGATTGGTCTTCCATCAATGAATCCTGGAAA	
GenBank L nucl.	5581	5640
HR L nucl.	AACCTGTACGCATTCCAGTCATCAGAACAGGAATTTGCCAGAGCAAAGAAGGTTAGTACA	
M2 L nucl.	AACCTGTACGCATTCCAGTCATCAGAACAGGAATTTGCCAGAGCAAAGAAGGTTAGTACA	
M4 L nucl.	.....	
	AACCTGTACGCATTCCAGTCATCAGAACAGGAATTTGCCAGAGCAAAGAAGGTTAGTACA	
GenBank L nucl.	5641	5700
HR L nucl.	TACTTTACCTTGACAGGTATTCCCTCCCAATTCATTCTGATCCTTTTGTGAACATTGAG	
M2 L nucl.	TACTTTACCTTGACAGGTATTCCCTCCCAATTCATTCTGATCCTTTTGTGAACATTGAG	
M4 L nucl.	.....	
	TACTTTACCTTGACAGGTATTCCCTCCCAATTCATTCTGATCCTTTTGTGAACATTGAG	
GenBank L nucl.	5701	5760
HR L nucl.	ACTATGCTACAAATATTTCGGAGTACCCACGGGTGTGTCTCATGCGGCTGCCTTAAAATCA	
M2 L nucl.	ACTATGCTACAAATATTTCGGAGTACCCACGGGTGTGTCTCATGCGGCTGCCTTAAAATCA	
M4 L nucl.	.....	
	ACTATGCTACAAATATTTCGGAGTACCCACGGGTGTGTCTCATGCGGCTGCCTTAAAATCA	
GenBank L nucl.	5761	5820
HR L nucl.	TCTGATAGACCTGCAGATTTATTGACCATTAGCCTTTTTTATATGGCGATTATATCGTAT	
M2 L nucl.	TCTGATAGACCTGCAGATTTATTGACCATTAGCCTTTTTTATATGGCGATTATATCGTAT	
M4 L nucl.	.....	
	TCTGATAGACCTGCAGATTTATTGACCATTAGCCTTTTTTATATGGCGATTATATCGTAT	

FIGURE 22-11



	5821	5880
GenBank L nucl.	TATAACATCAATCATATCAGAGTAGGACCGATACCTCCGAACCCCCCATCAGATGGAATT	
HR L nucl.	TATAACATCAATCATATCAGAGTAGGACCGATACCTCCGAACCCCCCATCAGATGGAATT	
M2 L nucl.	.....	
M4 L nucl.	TATAACATCAATCATATCAGAGTAGGACCGATACCTCCGAACCCCCCATCAGATGGAATT	
	5881	5940
GenBank L nucl.	GCACAAAATGTGGGGATCGCTATAACTGGTATAAGCTTTTGGCTGAGTTTGATGGAGAAA	
HR L nucl.	GCACAAAATGTGGGGATCGCTATAACTGGTATAAGCTTTTGGCTGAGTTTGATGGAGAAA	
M2 L nucl.	.....	
M4 L nucl.	GCACAAAATGTGGGGATCGCTATAACTGGTATAAGCTTTTGGCTGAGTTTGATGGAGAAA	
	5941	6000
GenBank L nucl.	GACATTCCACTATATCAACAGTGTTTAGCAGTTATCCAGCAATCATTCCCCGATTAGGTGG	
HR L nucl.	GACATTCCACTATATCAACAGTGTTTAGCAGTTATCCAGCAATCATTCCCCGATTAGGTGG	
M2 L nucl.	.....	
M4 L nucl.	GACATTCCACTATATCAACAGTGTTTAGCAGTTATCCAGCAATCATTCCCCGATTAGGTGG	
	6001	6060
GenBank L nucl.	GAGGCTGTTTCAGTAAAAGGAGGATACAAGCAGAAGTGGAGTACTAGAGGTGATGGGCTC	
HR L nucl.	GAGGCTGTTTCAGTAAAAGGAGGATACAAGCAGAAGTGGAGTACTAGAGGTGATGGGCTC	
M2 L nucl.	.....	
M4 L nucl.	GAGGCTGTTTCAGTAAAAGGAGGATACAAGCAGAAGTGGAGTACTAGAGGTGATGGGCTC	
	6061	6120
GenBank L nucl.	CCAAAAGATACCCGAATTTCAGACTCCTTGGCCCCAATCGGGAACCTGGATCAGATCTCTG	
HR L nucl.	CCAAAAGATACCCGAATTTCAGACTCCTTGGCCCCAATCGGGAACCTGGATCAGATCTCTG	
M2 L nucl.	.....	
M4 L nucl.	CCAAAAGATACCCGAATTTCAGACTCCTTGGCCCCAATCGGGAACCTGGATCAGATCTCTG	
	6121	6180
GenBank L nucl.	GAATTGGTCCGAAACCAAGTTCGTCTAAATCCATTCAATGAGATCTTGTTCAATCAGCTA	
HR L nucl.	GAATTGGTCCGAAACCAAGTTCGTCTAAATCCATTCAATGAGATCTTGTTCAATCAGCTA	
M2 L nucl.	.....	
M4 L nucl.	GAATTGGTCCGAAACCAAGTTCGTCTAAATCCATTCAATGAGATCTTGTTCAATCAGCTA	
	6181	6240
GenBank L nucl.	TGTCGTACAGTGGATAATCATTTGAAATGGTCAAATTTGCGAAAGAAACACAGGAATGATT	
HR L nucl.	TGTCGTACAGTGGATAATCATTTGAAATGGTCAAATTTGCGAAAAAACACAGGAATGATT	
M2 L nucl.	.....	
M4 L nucl.	TGTCGTACAGTGGATAATCATTTGAAATGGTCAAATTTGCGAAAAAACACAGGAATGATT	
	6241	6300
GenBank L nucl.	GAATGGATCAATAGACGAATTTCAAAAAGAAGACCGGTCTATACTGATGTTGAAGAGTGAC	
HR L nucl.	GAATGGATCAATAGACGAATTTCAAAAAGAAGACCGGTCTATACTGATGTTGAAGAGTGAC	
M2 L nucl.	.....	
M4 L nucl.	GAATGGATCAATAGACGAATTTCAAAAAGAAGACCGGTCTATACTGATGTTGAAGAGTGAC	

FIGURE 22-12



	6301	6360
GenBank L nucl.	CTACACGAGGAAAACTCTTGGAGAGATTAA.....	
HR L nucl.	CTACATGAGGAAAACTCTTGGAGAGATTAAAAAATCATGAGGAGACTCCAACTTTAAGT	
M2 L nucl.	.....	
M4 L nucl.	CTACATGAGGAAAACTCTTGGAGAGATTAA.....	
	6361	6395
GenBank L nucl.	.....	
HR L nucl.	ATGAAAAAACTTTGATCCTTAAGACCCTCTTGTG	
M2 L nucl.	.....	
M4 L nucl.	.....	

**FIGURE 22-13**



GenBank L	a.a.	1	60
HR L a.a.		MEVHDFETDEFNDFNEDDYATREFLNPNDERMTYLNHADYNLNSPLISDDIDNLIRKFNSL	
M4 L a.a.		MEVHDFETDEFNDFNEDDYATREFLNPNDERMTYLNHADYNLNSPLISDDIDNLIRKFNSL	
GenBank L	a.a.	61	120
HR L a.a.		PIPSMWDSKNWDGVLEMLTSCQANPISTSQMHKWMGSWLMSDNHDASQGYSLHEVDKEA	
M4 L a.a.		PIPSMWDSKNWDGVLEMLTSCQANPISTSQMHKWMGSWLMSDNHDASQGYSLHEVDKEA	
GenBank L	a.a.	121	180
HR L a.a.		EITFDVVETFIRGWGNKPIEYIKKERWTDSFKILAYLCQKFLDLHKLTLILNAVSEVELL	
M4 L a.a.		EITFDVVETFIRGWGNKPIEYIKKERWTDSFKILAYLCQKFLDLHKLTLILNAVSEVELL	
GenBank L	a.a.	181	240
HR L a.a.		NLARTFKGKVRSSSHGTNICRIRVPSLGPTFISEGWAYFKKLDILMDRNFLLMVKDVIIG	
M4 L a.a.		NLARTFKGKVRSSSHGTNICRLRVPSLGPTFISEGWAYFKKLDILMDRNFLLMVKDVIIG	
GenBank L	a.a.	241	300
HR L a.a.		RMQTVLSMVCRIDNLFSEQDIFSLNLIYRIGDKIVERQGNFSYDLIKMVEPICNLRLMKL	
M4 L a.a.		RMQTVLSMVCRIDNLFSEQDIFSLNLIYRIGDKIVERQGNFSYDLIKMVEPICNLRLMKL	
GenBank L	a.a.	301	360
HR L a.a.		ARESRLVPQFPFHENHIKTSVDEGAKIDRGIRFLHDQIMSVKTVDLTLVIYGSFRHWGH	
M4 L a.a.		ARESRLVPQFPFHENHIKTSVDEGAKIDRGIRFLHDQIMSVKTVDLTLVIYGSFRHWGH	
GenBank L	a.a.	361	420
HR L a.a.		PFIDYYIGLEKLHSQVTMKKDIDVSYAKALASDLARIVLFQQFNDHKKWFVNGDLLPHDH	
M4_L.pro		PFIDYYAGLEKLHSQVTMKKDIDVSYAKALASDLARIVLFQQFNDHKKWFVNGDLLPHDH	
GenBank L	a.a.	421	480
HR L a.a.		PFKSHVKENTWPTAAQVQDFGDKWHELPLIKCFEIPDLLDPSIIYSDKSHSMNRSEVLKH	
M4 L a.a.		PFKSHVKENTWPTAAQVQDFGDKWHELPLIKCFEIPDLLDPSIIYSDKSHSMNRSEVLKH	
GenBank L	a.a.	481	540
HR L a.a.		VRMNPNTPIPSKKVLQTMLDTKATNWKEFLKEIDEKGLDDDDLIIGLKGKERELKLAGRF	
M4 L a.a.		VRMNPNTPIPSKKVLQTMLDTKATNWKEFLKEIDEKGLDDDDLIIGLKGKERELKLAGRF	
GenBank L	a.a.	541	600
HR L a.a.		FSLMSWKLREYFVITEYLIKTHFVPMFKGLTMADDLTAVIKKMLDSSSGQGLKSYEAICI	
M4 L a.a.		FSLMSWKLREYFVITEYLIKTHFVPMFKGLTMADDLTAVIKKMLDSSSGQGLKSYEAICI	

FIGURE 23-1



GenBank L	a.a.	601	660
HR L a.a.		ANHIDYEKWNHQRKLSNGPVFRVMGQFLGYPSLIERTHEFFEKSIIYNGRPDLMRVHN	
M4 L a.a.		ANHIDYEKWNHQRKLSNGPVFRVMGQFLGYPSLIERTHEFFEKSIIYNGRPDLMRVHN	
GenBank L	a.a.	661	720
HR L a.a.		NTLINSTSQRVCWQGQEGGLEGLRQKGWILNLLVIQREAKIRNTAVKVLAQGDNQVICT	
M4 L a.a.		NTLINSTSQRVCWQGQEGGLEGLRQKGWSILNLLVIQREAKIRNTAVKVLAQGDNQVICT	
GenBank L	a.a.	721	780
HR L a.a.		QYKTKKSRNVVELQGALNQMVSNNEKIMTAIKIGTGKLGLLINDDETMQSADYLNYGKIP	
M4 L a.a.		QYKTKKSRNVVELQGALNQMVSNNEKIMTAIKIGTGKLGLLINDDETMQSADYLNYGKIP	
GenBank L	a.a.	781	840
HR L a.a.		IFRGVIRGLETKRWSRVTCVTNDQIPTCANIMSSVSTNALTVAHFAENPINAMIQYNYFG	
M4 L a.a.		IFRGVIRGLETKRWSRVTCVTNDQIPTCANIMSSVSTNALTVAHFAENPINAMIQYNYFG	
GenBank L	a.a.	841	900
HR L a.a.		TFARLLLMMHDPALRQSLYEVQDKIPGLHSSTFKYAMLYLDPSIGGVSGMSLSRFLIRAF	
M4 L a.a.		TFARLLLMMHDPALRQSLYEVQDKIPGLHSSTFKYAMLYLDPSIGGVSGMSLSRFLIRAF	
GenBank L	a.a.	901	960
HR L a.a.		PDPVTESLSFWRFIHVHARSEHLKEMSAVFGNPEIAKFRITHIDKLVEDPTSLNIAMGMS	
M4 L a.a.		PDPVTESLSFWRFIHVHARSEHLKEMSAVFGNPEIAKFRITHIDKLVEDPTSLNIAMGMS	
GenBank L	a.a.	961	1020
HR L a.a.		PANLLKTEVKKCLIESRQTIRNQVIKDATTIYLYHEEDRLRSFLWSINPLFPRFLSEFKSG	
M4 L a.a.		PANLLKTEVKKCLIESRQTIRNQVIKDATTIYLYHEEDRLRSFLWSINPLFPRFLSEFKSG	
GenBank L	a.a.	1021	1080
HR L a.a.		TFLGVADGLISLFQNSRTIRNSFKKKYHREDDLIVRSEVSSLTHLGKLHLRRGSCKMWT	
M4 L a.a.		TFLGVADGLISLFQNSRTIRNSFKKKYHREDDLIVRSEVSSLTHLGKLHLRRGSCKMWT	
GenBank L	a.a.	1081	1140
HR L a.a.		CSATHADTLRYKSWGRTVIGTTVPHPLEMLGPQHRKETPCAPCNTSGFNYSVHCPDGIH	
M4 L a.a.		CSATHADTLRYKSWGRTVIGTTVPHPLEMLGPQHRKETPCAPCNTSGFNYSVHCPDGIH	
GenBank L	a.a.	1141	1200
HR L a.a.		DVFSSRGPLPAYLGSKTSESTSILQPWERESKVPLIKRATRLRDAISWFVEPDSKLAMTI	
M4 L a.a.		DVFSSRGPLPAYLGSKTSESTSILQPWERESKVPLIKRATRLRDAISWFVEPDSKLAMTI	

FIGURE 23-2



GenBank L	a.a.	1201	1260
HR L a.a.		LSNIHSLTGEEWTKRQHGFKRTGSALHRFSTSRMSHGGFASQSTAALTRLMATTTDTMRDL	
M4 L a.a.		LSNIHSLTGEEWTKRQHGFKRTGSALHRFSTSRMSHGGFASQSTAALTRLMATTTDTMRDL	
GenBank L	a.a.	1261	1320
HR L a.a.		GDQNFDFLFQATLLYAQITTTVARDGWITSCTDHYHIACKSCLRPIEEITLDSSMDYTPP	
M4 L a.a.		GDQNFDFLFQATLLYAQITTTVARDGWITSCTDHYHIACKSCLRPIEEITLDSSMDYTPP	
GenBank L	a.a.	1321	1380
HR L a.a.		DVSHVLKTRWNGEGSWGQEI KQIYPLEGNWKNLAPAEQSYQVGR CIGFLYGD LAYRKSTH	
M4 L a.a.		DVSHVLKTRWNGEGSWGQEI KQIYPLEGNWKNLAPAEQSYQVGR CIGFLYGD LAYRKSTH	
GenBank L	a.a.	1381	1440
HR L a.a.		AEDSSLFPLSIQGRIRGRGFLKGLLDGLMRASCCQVIHRRSLAHLKR PANAVYGG LIYLI	
M4 L a.a.		AEDSSLFPLSIQGRIRGRGFLKGLLDGLMRASCCQVIHRRSLAHLKR PANAVYGG LIYLI	
GenBank L	a.a.	1441	1500
HR L a.a.		DKLSVSPPFLSLTRSGPIRDELETIPHKIPTSYPTSNRDMGVIVRNYFKYQCRLIEKGKY	
M4 L a.a.		DKLSVSPPFLSLTRSGPIRDELETIPHKIPTSYPTSNRDMGVIVRNYFKYQCRLIEKGKY	
GenBank L	a.a.	1501	1560
HR L a.a.		RSHYSQLWLFSVDVLSIDFIGPFSISTTLLQILYKPF LSGDKNELREL ANLSSLLRS GEG	
M4 L a.a.		RSHYSQLWLFSVDVLSIDFIGPFSISTTLLQILYKPF LSGDKNELREL ANLSSLLRS GEG	
GenBank L	a.a.	1561	1620
HR L a.a.		WEDIHVKFFTKDILLCP E EIRHACKFGIAKDNNK DMSYPPWGRESRGTIT TTPVYYTTTP	
M4 L a.a.		WEDIHVKFFTKDILLCP E EIRHACKFGIAKDNNK DMSYPPWGRESRGTIT TTPVYYTTTP	
GenBank L	a.a.	1621	1680
HR L a.a.		YPKM LEMPPRIQNPLLSGIRLGQLPTGAHYKIRSILHGMGIHYRDFLSCGDGSGGMTAAL	
M4 L a.a.		YPKM LEMPPRIQNPLLSGIRLGQLPTGAHYKIRSILHGMGIHYRDFLSCGDGSGGMTAAL	
GenBank L	a.a.	1681	1740
HR L a.a.		LRENVH SRGIFNSLLELSGSVMRGASPEPPSALET LGGDKSRCVNGETCWEYPSDLCDPR	
M4 L a.a.		LRENVH SRGIFNSLLELSGSVMRGASPEPPSALET LGGDKSRCVNGETCWEYPSDLCDPR	
GenBank L	a.a.	1741	1800
HR L a.a.		TWDYFLRLKAGLGLQIDLIVMDMEVRDSSTSLKIETNVRNYVHRILDEQGVLIYKTYGTY	
M4 L a.a.		TWDYFLRLKAGLGLQIDLIVMDMEVRDSSTSLKIETNVRNYVHRILDEQGVLIYKTYGTY	
GenBank L	a.a.	1801	1860
HR L a.a.		ICESEKNAV TILGPMFKTVDLVQTEFSSSQ TSEVYMVCKGLKKLIDEPNPDWSSINESWK	
M4 L a.a.		ICESEKNAV TILGPMFKTVDLVQTEFSSSQ TSEVYMVCKGLKKLIDEPNPDWSSINESWK	

FIGURE 23-3



GenBank L	a.a.	1861	1920
HR L a.a.		NLYAFQSSEQEFARAKKVSTYFTLTGIPSQFIPDPFVNIETMLQIFGVPTGVSHAAALKS	
M4 L a.a.		NLYAFQSSEQEFARAKKVSTYFTLTGIPSQFIPDPFVNIETMLQIFGVPTGVSHAAALKS	
GenBank L	a.a.	1921	1980
HR L a.a.		SDRPADLLTISLFYMAIISYYNINHIRVGPIPPNPPSDGIAQNVGIAITGISFWLSLMEK	
M4 L a.a.		SDRPADLLTISLFYMAIISYYNINHIRVGPIPPNPPSDGIAQNVGIAITGISFWLSLMEK	
GenBank L	a.a.	1981	2040
HR L a.a.		DIPLYQQCLAVIQQSFPPIRWEAVSVKGGYKQKWSTRGDGLPKDTRISDSLAPIGNWIRSL	
M4 L a.a.		DIPLYQQCLAVIQQSFPPIRWEAVSVKGGYKQKWSTRGDGLPKDTRISDSLAPIGNWIRSL	
GenBank L	a.a.	2041	2100
HR L a.a.		ELVRNQVRLNPFNEILFNQLCRTVDNHLKWSNLRKNTGMIEWINRRISKEDRSILMLKSD	
M4 L a.a.		ELVRNQVRLNPFNEILFNQLCRTVDNHLKWSNLRKNTGMIEWINRRISKEDRSILMLKSD	
GenBank L	a.a.	2101	2110
HR L a.a.		LHEENSWRD	
M4 L a.a.		LHEENSWRD	

FIGURE 23-4



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ance Notes on Codes and Abbreviations" appearing at the begin-  
ning of each regular issue of the PCT Gazette.*

(54) Title: ONCOLYTIC VIRUS

(57) Abstract: The present invention is directed to a method of reducing the viability of a tumor cell involving administering a virus that is not a common human pathogen to the tumor cell. Preferably, the virus exhibits differential susceptibility, in that normal cells are not affected by the virus. This differential susceptibility is more pronounced in the presence of interferon. The tumor cell is characterized by having low levels, or no. PKR activity, or as being PKR<sup>-/-</sup>, STAT1<sup>-/-</sup> or both PKR<sup>-/-</sup> and STAT1<sup>-/-</sup>. The virus is selected from the group consisting of Rhabdovirus and picornavirus, and preferably is vesicular stomatitis virus (VSV) or a derivative thereof.

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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/25510

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61K35/76 A61P35/00 C12N7/00 C12N7/02 C12N15/47  
/(A61K35/76,38:21)

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, BIOSIS, MEDLINE, CHEM ABS Data, EMBASE, SCISEARCH

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 18799 A (ROBERTS MICHAEL S ;PRO VIRUS INC (US); RABIN HARVEY (US); GROENE W) 22 April 1999 (1999-04-22) cited in the application abstract page 6, paragraph 4 -page 7, paragraph 1 page 13, paragraph 2 page 23, paragraph 3 claims 1,116,117; examples 26,27 ---	1-51, 64-80
X	WO 99 45783 A (MOLNAR KIMBER KATHERINE L ;UNIV PENNSYLVANIA (US); COUKOS GEORGE () 16 September 1999 (1999-09-16)  abstract page 15, paragraph 2 claims 1,19 ---	1-23, 25-37, 64-74, 76-80
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/25510

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 34625 A (ROSE JOHN K ;UNIV YALE (US)) 7 November 1996 (1996-11-07)  abstract page 51, line 9 - line 22 page 73, paragraph 1 -page 106, paragraph 1  ---	1-37, 64-74, 76-80
X	NICKELS MICHAEL S ET AL: "Identification of an amino acid change that affects N protein function in vesicular stomatitis virus." JOURNAL OF GENERAL VIROLOGY, vol. 75, no. 12, 1994, pages 3591-3595, XP002162485 ISSN: 0022-1317 the whole document  ---	59,60
A	SCHUBERT M ET AL: "PRIMARY STRUCTURE OF THE VESICULAR STOMATITIS VIRUS POLYMERASE L GENE EVIDENCE FOR A HIGH FREQUENCY OF MUTATIONS" JOURNAL OF VIROLOGY, vol. 51, no. 2, 1984, pages 505-514, XP000982855 ISSN: 0022-538X the whole document  ---	63
A	FRANCOEUR A M ET AL: "THE ISOLATION OF INTERFERON-INDUCING MUTANTS OF VESICULAR STOMATITIS VIRUS WITH ALTERED VIRAL P FUNCTION FOR THE INHIBITION OF TOTAL PROTEIN SYNTHESIS" VIROLOGY, vol. 160, no. 1, 1987, pages 236-245, XP000982787 ISSN: 0042-6822 cited in the application the whole document  ---	26-31, 59-63,76
A	BALACHANDRAN SIDDHARTH ET AL: "Activation of the dsRNA-dependent protein kinase, PKR, induces apoptosis through FADD-mediated death signaling" EMBO JOURNAL,OXFORD UNIVERSITY PRESS, SURREY,GB, vol. 17, no. 23, 1 December 1998 (1998-12-01), pages 6888-6902, XP002159409 ISSN: 0261-4189 the whole document  ---  -/--	18,19, 70,71



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/25510

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DURBIN J E ET AL: "TARGETED DISRUPTION OF THE MOUSE STAT1 GENE RESULTS IN COMPROMISED INNATE IMMUNITY TO VIRAL DISEASE" CELL, CELL PRESS, CAMBRIDGE, MA, US, vol. 84, 9 February 1996 (1996-02-09), pages 443-450, XP000941705 ISSN: 0092-8674 the whole document	
P,X	--- STOJDL DAVID F ET AL: "Exploiting tumor-specific defects in the interferon pathway with a previously unknown oncolytic virus." NATURE MEDICINE, vol. 6, no. 7, July 2000 (2000-07), pages 821-825, XP002162486 ISSN: 1078-8956 the whole document	1-51, 64-80
P,X	--- BALACHANDRAN SIDDHARTH ET AL: "Vesicular stomatitis virus (VSV) therapy of tumors." IUBMB LIFE, vol. 50, no. 2, August 2000 (2000-08), pages 135-138, XP000982784 ISSN: 1521-6543 the whole document	1-51, 64-80
E	--- WO 00 62735 A (ROBERTS MICHAEL S ;PRO VIRUS INC (US); RABIN HARVEY (US); GROENE W) 26 October 2000 (2000-10-26) claims 1,116,117134; example 26 -----	1-51, 64-80



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 00/25510

### Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
**Although claims 1-31, 35-37 (in so far as it relates to in vivo methods), 32-34 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.**
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

**see additional sheet**

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**see further information sheet invention 1.**

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.



## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: (1-20,32-34,38,41-45,48-51,64-72,78-80 partially),  
21-31,35-37,39,40,46,47,59-63,73-77

- 1.1. Claims: 1-26,32-37,64-80 (partially),27  
a method of reducing the viability of a tumor cell,  
comprising administering to the tumor cell a virus,  
wherein said virus is the attenuated strain M1 of  
vesicular stomatitis virus, and said tumor cell is a  
carcinoma, a hematopoietic tumor cell, a glioblastoma,  
a melanoma, a sarcoma or a neuroendocrine tumor.

- 1.2. Claims: 1-26,32-37,64-80 (partially),28  
a method of reducing the viability of a tumor cell,  
comprising administering to the tumor cell a virus,  
wherein said virus is the attenuated strain M2 of  
vesicular stomatitis virus, and said tumor cell is a  
carcinoma, a hematopoietic tumor cell, a glioblastoma,  
a melanoma, a sarcoma or a neuroendocrine tumor.

- 1.3. Claims: 1-26,32-37,64-80 (partially),29  
a method of reducing the viability of a tumor cell,  
comprising administering to the tumor cell a virus,  
wherein said virus is the attenuated strain M3 of  
vesicular stomatitis virus, and said tumor cell is a  
carcinoma, a hematopoietic tumor cell, a glioblastoma,  
a melanoma, a sarcoma or a neuroendocrine tumor.

- 1.4. Claims: 1-26,32-37,64-80 (partially),30  
a method of reducing the viability of a tumor cell,  
comprising administering to the tumor cell a virus,  
wherein said virus is the attenuated strain M4 of  
vesicular stomatitis virus, and said tumor cell is a  
carcinoma, a hematopoietic tumor cell, a glioblastoma,  
a melanoma, a sarcoma or a neuroendocrine tumor.

- 1.5. Claims: 1-26,32-37,64-80 (partially),31  
a method of reducing the viability of a tumor cell,  
comprising administering to the tumor cell a virus,  
wherein said virus is the attenuated strain M5 of  
vesicular stomatitis virus, and said tumor cell is a  
carcinoma, a hematopoietic tumor cell, a glioblastoma,  
a melanoma, a sarcoma or a neuroendocrine tumor.

- 1.6. Claims: 38,41-45,48-51 (partially),39-40,46,47



## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

a method for identifying a tumor susceptible to treatment with a Rhabdovirus, comprising:  
 (a) dividing a sample containing cells of the tumor into a first portion and a second portion;  
 (b) treating the first portion with the virus; and  
 (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion,  
 wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion

a method for identifying a tumor susceptible to treatment with a Rhabdovirus, comprising:  
 (a) dividing a sample containing cells of the tumor into a first portion and a second portion;  
 (b) treating the first portion with the virus and an amount of interferon sufficient to improve survival of interferon-responsive cells in the presence of the virus, and treating the second portion with the virus in the absence of interferon; and  
 (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion,  
 wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion

## 1.7. Claim : 59

an isolated nucleic acid molecule having a sequence comprising  
 (a) a sequence coding for a protein comprising the amino acid sequence of protein N of a VSV strain selected from the group consisting of HR and M3 shown in figure 15; or  
 (b) N gene cDNA sequence of a VSV strain selected from the group consisting of HR, M2 and M3 shown in figure 14; or  
 (c) RNA sequence corresponding to (b); or  
 (d) a sequence complementary to (a), (b) or (c)

## 1.8. Claim : 60

an isolated nucleic acid molecule having a sequence comprising  
 (a) a sequence coding for a protein comprising the amino acid sequence of protein P of a VSV strain selected from the group consisting of HR and M3 and M4 shown in figure 17; or  
 (b) P gene cDNA sequence of a VSV strain selected from the group consisting of HR, M3 and M4 shown in figure 16; or  
 (c) RNA sequence corresponding to (b); or  
 (d) a sequence complementary to (a), (b) or (c).



## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

## 1.9. Claim : 61

an isolated nucleic acid molecule having a sequence comprising

- (a) a sequence coding for a protein comprising the amino acid sequence of protein M of a VSV strain selected from the group consisting of HR and M3 and M4 shown in figure 19; or
- (b) M gene cDNA sequence of a VSV strain selected from the group consisting of HR, M3 and M4 shown in figure 18; or
- (c) RNA sequence corresponding to (b); or
- (d) a sequence complementary to (a), (b) or (c).

## 1.10. Claim : 62

an isolated nucleic acid molecule having a sequence comprising

- (a) a sequence coding for a protein comprising the amino acid sequence of protein G of a VSV strain M3 shown in figure 21; or
- (b) G gene cDNA sequence of a VSV strain M3 shown in figure 20; or
- (c) RNA sequence corresponding to (b); or
- (d) a sequence complementary to (a), (b) or (c).

## 1.11. Claim : 63

an isolated nucleic acid molecule having a sequence comprising

- (a) a sequence coding for a protein comprising the amino acid sequence of protein L of a VSV strain M4 shown in figure 23; or
- (b) L gene cDNA sequence of a VSV strain M4 shown in figure 16; or
- (c) RNA sequence corresponding to (b); or
- (d) a sequence complementary to (a), (b) or (c).

## 2. Claims: 1-20,32-34,38,41-45,48-51,64-72,78-80 partially

a method of reducing the viability of a tumor cell, comprising administering to the tumor cell a virus, wherein said virus is a picornavirus virus, and said tumor cell is a carcinoma, a hematopoietic tumor cell, a glioblastoma, a melanoma, a sarcoma or a neuroendocrine tumor.

a method for identifying a tumor susceptible to treatment with a picornavirus, comprising:

- (a) dividing a sample containing cells of the tumor into a first portion and a second portion;
- (b) treating the first portion with the virus; and
- (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion,



## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion

a method for identifying a tumor susceptible to treatment with a picornavirus, comprising:

- (a) dividing a sample containing cells of the tumor into a first portion and a second portion;
- (b) treating the first portion with the virus and an amount of interferon sufficient to improve survival of interferon-responsive cells in the presence of the virus, and treating the second portion with the virus in the absence of interferon; and
- (c) determining whether the percentage of dead cells in the first portion is higher than in the second portion, wherein the tumor is susceptible to treatment with the virus if the percentage of dead cells in the first portion is higher than in the second portion

## 3. Claims: 52-58

a method for purifying a vesicular stomatitis virus, comprising adding a sample containing the virus to an affinity matrix to produce the virus bound to the affinity matrix; washing the bound virus; and eluting the bound virus from the affinity matrix

a modified vesicular stomatitis virus expressing a non-native protein on its surface

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/25510

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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